PATIENT AND PHYSICIAN PREFERENCES FOR NON-INVASIVE DIAGNOSTIC CARDIAC IMAGING TECHNOLOGIES: A DISCRETE CHOICE EXPERIMENT

BY

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ABSTRACT

BACKGROUND: The use of non-invasive cardiovascular imaging tests for diagnosing coronary artery disease (CAD) has risen dramatically over the last decade. However, guidelines for the diagnosis and management of patients with stable ischemic heart disease reported a lack of attention devoted to users' satisfaction, and repeatedly documented the importance of patient-oriented research to guide clinical decision-making. In this context, this study aims to contribute to the understanding of patient and physician preference in relation to the choice of cardiovascular imaging tests. METHODS: A discrete choice experiment (DCE) questionnaire on a convenience sample from the Royal Victoria cardiology clinic was used to systematically elicit patient and physician preference toward diagnostic imaging tests. Tests were differentiated using 6 attributes (patient out-of-pocket cost, risks and side effects, type of procedures, diagnostic accuracy, type of scanner and test duration). A choice-based conjoint analysis with hierarchical Bayes estimation was performed with Sawtooth Software. RESULTS: One hundred and forty-eight cardiac patients and 63 physicians completed the DCE. Risks and side effects had the highest impact on patients' preference (30%). Patients assigned notably high utility to tests with milder side effects (+97.7), while avoiding exposure to ionizing radiation (-36.7) and risks associated with exercise and the use of pharmacological agents inducing direct coronary arteriolar vasodilation (-61.0). Physicians attributed more importance to costs for patients (29%). CONCLUSIONS: Patients' preference was most determined by the risks and side effects associated with cardiovascular imaging tests, while physicians preferred less costly alternatives. When engaging in shared decision-making with patients, physicians should discuss the risks and side effects associated with cardiovascular imaging tests. In aiming for the best possible care, the clinical implementation of safer, more accurate and cost-effective imaging tests for diagnosing CAD may improve users' satisfaction and health outcomes.

RÉSUMÉ

CONTEXTE: L'utilisation de tests d'imagerie cardiovasculaire non invasifs pour le diagnostic de la maladie coronarienne (CAD) a rapidement augmenté au cours de la dernière décennie. Cependant, des recommandations pour le diagnostic et la gestion des patients atteints de cardiopathie ischémique stable ont signalé un manque d'attention consacré à la satisfaction des utilisateurs, et documenté à plusieurs reprises l'importance de la recherche axée sur le patient pour guider la prise de décision clinique. Dans ce contexte, cette étude vise à contribuer à la compréhension des préférences des patients et des médecins par rapport à leur choix de tests d'imagerie cardiovasculaire. MÉTHODES: Un questionnaire *discrete choice experiment* (DCE) sur un échantillon de la clinique de cardiologie Royal Victoria a été utilisé pour déterminer systématiquement les préférences des patients et des médecins à l'égard des tests d'imagerie diagnostique. Les tests ont été différenciés en utilisant 6 attributs (coût pour le patient, risques et effets secondaires, type de procédures, précision du diagnostic, type de scanner et durée du test). Une estimation bayésienne hiérarchique conjointe basée sur le choix a été réalisée avec Sawtooth Software. RÉSULTATS: Cent quarante-huit patients cardiaques et 63 médecins ont complété le DCE. Les risques et les effets secondaires ont eu le plus grand impact sur la préférence des patients (30%). Les patients ont donné une utilité particulièrement élevée pour les tests avec effets secondaires légers (+97,7), tout en évitant l'exposition à la radiation ionisante (-36,7) et les risques associés à l'exercice et l'utilisation d'agents pharmacologiques induisant une vasodilatation artériolaire coronaire directe (-61,0). Les médecins attribuaient plus d'importance aux coûts pour les patients (29%). CONCLUSIONS: La préférence des patients était surtout déterminée par les risques et les effets secondaires associés aux tests d'imagerie cardiovasculaire, alors que les médecins préféraient des alternatives moins coûteuses. Lorsqu'ils participent à la prise de décision partagée avec les patients, les médecins devraient discuter des risques et des effets secondaires associés aux tests d'imagerie cardiovasculaire. En cherchant à obtenir les meilleurs soins possibles, la mise en œuvre clinique de tests d'imagerie plus sûrs, plus précis et plus rentables pour le diagnostic de la coronaropathie peut améliorer la satisfaction des utilisateurs et les résultats pour la santé.

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LIST OF ABBREVIATIONS & ACRONYMS

ACBC	Adaptive Choice-Based Conjoint
ACC	American College of Cardiology
AHA	American Heart Association
AUC	Appropriate use criteria
b-CMR	Breathing-induced oxygenation-sensitive cardiac magnetic resonance
CAD	Coronary artery disease
CBC	Choice-based conjoint
CCEIAS	Comité de coordination des ententes interprovinciales en assurance santé
CMR	Cardiovascular magnetic resonance
CMS	Centers for Medicare & Medical Services
CT	Computed tomography
CTA	Computed tomographic angiography
CTGQ	Cells, Tissues, Genetics & Qualitative research panel
DCE	Discrete choice experiment
DNA	Deoxyribonucleic acid
HB	Hierarchical Bayes
ICA	Invasive coronary angiography
ISPOR	International Society for Pharmacoeconomics and Outcomes Research
NAPCRG	North American Primary Care Research Group
MUHC	McGill University Health Center
MRI	Magnetic resonance imaging
OHIP	Ontario Health Insurance Program
PCC	Patient-centered care
PET	Positron emission tomography
RAMQ	Régie de l'assurance maladie du Québec
RI-MUHC	Research Institute of the McGill University Health Center
SCCT	Society of Cardiovascular Computed Tomography
SPECT	Single photon emission computed tomography
SPSS	Statistical Package for the Social Science

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1. INTRODUCTION

1.1. Rationale

Patient-centered medicine places the patient at the center of their own healthcare. It focuses on providing care that is respectful of patients' preferences, needs, and values while ensuring that patients' values guide all clinical decisions (Wilkerson et., 2010). With this modern approach to professional care, a balance between the evidence-based medicine and the personal satisfaction and well-being of patients and their family is fundamental. Thus, sustained and appropriate doctor-patient communication and relationships are highly valued for enriched healthcare delivery. To facilitate communication between patients and physicians, it is important that physicians remain attentive to issues such as patient preference while recognizing that their own preference and what they think may be the best treatment for their patient may not be accurate (Mühlbacher & Nübling, 2011; Gunn et al., 2013). The implication of patient preference in medicine has been overlooked, and evidence suggests that physicians often do not fully understand their patients' preferences about treatment decisions, which can lead to silent (or preference) misdiagnosis (Mulley et al., 2012; Harrison et al., 2017). Knowledge about patient and physician preferences is also important because it helps to promote an informed dialogue between patients and their healthcare professional (Mühlbacher & Juhnke, 2013; Agarwal et al., 2015).

To provide insights on patient preferences, there has been a notable increase in patient-centered research in the last two decades (Oates et al., 2000; October et al., 2016). Among other methods used to elicit preferences, discrete choice experiments (DCE) have been used increasingly in healthcare and in health economics research (Clark et al., 2014; Adams et al., 2015). A DCE is an attribute-based survey method commonly used to elicit preferences for healthcare services or technologies. DCEs are based on Lancaster's (1966) theory for measuring the utility of distinctive services of interest by presenting research participants with samples of unique hypothetical scenarios from which they are asked to choose the one they prefer. By asking participants to answer several choice questions within a single survey, it is possible to estimate what characteristics of the services influence participants' decisions and to evaluate the relative importance they allocate

to these characteristics (Mangham et al., 2008). Health researchers have been applying DCEs to direct evaluation of various policy-relevant characteristics (attributes) of healthcare services, to gauge the uptake or demand forecasting and to understand the roots of patient satisfaction and compliance to treatment (Ryan et al., 2007). This attribute-based survey method has been shown to be of particular value when estimating the relevance and acceptability of novel medical tools and treatments prior to their clinical implementation, thus averting prospective barriers to clinical use (Mandeville et al., 2014). By providing systematic information on healthcare users' preference, DCEs can also be used to inspire and guide future medical innovations.

For the last 15 years, coronary artery disease (CAD) has remained the leading cause of death globally (WHO, 2016). To identify and diagnose this important disease, the use of non-invasive cardiovascular imaging tests has risen dramatically over the last decade. Technological advances have allowed for the development of innovative imaging protocols for the diagnosis of CAD (Ladapo et al., 2014; Mordi et al., 2017). Considering the importance of managed care, the cost-effectiveness of medical interventions has come into sharper focus in medical decision-making, and the decision to choose a test over another has primarily been made by incorporating clinical data, costs, and other tests' strengths and limitations (Thom et al., 2014). With the growing number of alternative imaging techniques and comparative effectiveness, there have been reports of a need for guidance on the benefits, costs, and place of these different techniques in the diagnostic pathway (Fihn et al. 2012). The benefits of patient-centered care (Oates et al., 2000) have encouraged the American Heart Association (AHA) and the American College of Cardiology (ACC) to document the importance of patient-oriented research to guide clinical decision-making. Nonetheless, most of the time and effort have been spent on technological breakthroughs, while little attention has been devoted to patients' satisfaction (van Waardhuizen et al., 2016). Recognizing this gap in literature, guidelines for the diagnosis and management of patients with stable ischemic heart disease reported on the need for preference studies to help inform referring physicians about what is an acceptable balance between the underdiagnosis and overdiagnosis of CAD (Fihn et al. 2012; Nishimura et al., 2014; Mancini et al., 2014).

To our knowledge, no research has examined patient and physician preferences for non-invasive cardiovascular imaging modalities and tests for diagnosing CAD. As mentioned

previously, when assessing users' preferences in healthcare, DCEs have become a commonly used instrument (de Bekker-Grob, 2012; Luyten et al., 2015). Therefore, a cross-sectional DCE study examining and comparing the preference of 1) patients who were most likely to undergo imaging to characterize coronary stenosis, and 2) physicians who were most likely to order a cardiac imaging test for their patient, toward current cardiovascular imaging tests and modalities was conducted.

1.2. Objectives

Placing value in a patient-centered approach to medicine, the primary objective of this study was to inform healthcare professionals and policy-makers by contributing to the understanding of patient and physician preferences in relation to the choice of advanced non-invasive cardiovascular tests and imaging modalities used for diagnosing coronary heart disease. To achieve this, current advanced non-invasive cardiovascular imaging tests for diagnosing CAD have been described in terms of their main differentiating attributes (costs, risks and side effects, type of procedures, diagnostic accuracy, type of scanner and test duration).

1.2.1. Secondary Objectives

Secondary objectives have been used to support the primary objective of this study. Thus, the secondary objectives of this study were 1) to understand which cardiovascular imaging test attributes, relative to each other, are most important to patients and to physicians and likely to influence their decision-making, 2) to quantify the utilities and trade-offs of imaging alternatives from the perspective of patients and physicians, 3) to appraise the concordance and discordance between patients' and physicians' preferences for cardiovascular imaging tests, and 4) to estimate the shares of preferences toward current non-invasive cardiovascular imaging tests for diagnosing CAD.

2. LITERATURE REVIEW

2.1. CARDIOVASCULAR IMAGING

Coronary artery disease is the single most common cause of death globally and is responsible for nearly 1 in every 5 deaths in developed countries (Mozaffarian et al., 2016; World Health Organization, 2016). In Canada, cardiovascular diseases account for nearly a third of crude mortality rates, and over half of these are caused by CAD (Statistics Canada, 2017). Recognizing the social and financial burden associated with CAD, continued technological developments in cardiovascular imaging have offered improved screening practices, with noticeable improvements in diagnosis and outcome for patients (Tilkemeier et al., 2016; Ayerbe et al., 2016). In Canada, the advances in medical imaging and the use of advanced imaging techniques have greatly contributed to improving the trends in cardiovascular mortality (Blais & Rochette, 2015). Patients with typical cardiac symptoms such as chest pain, shortness of breath, and numbness in the arm are most likely to be screened for CAD (Rashid et al., 2014). The non-invasive assessment of CAD is typically performed through stress testing techniques, with or without using cardiac imaging. Stress testing has been used since the late 1920s as a non-invasive way to assess for exercise-induced myocardial ischemia (Master & Oppenheimer, 1929). Such approaches involve provoking a controlled cardiovascular stress response, which can be induced by exercise, pharmacologic agents, or, more recently, breathing maneuvers. While vasodilatory agents modify blood flow without significantly affecting myocardial workload, exercise increases myocardial oxygen demand that may not be met in the presence of coronary artery stenosis. At rest, blood perfusion may be sufficient to meet myocardial demand, but stress testing allows to assess the mismatch between blood demand and blood supply. If the associated stenosis is severe, this results in myocardial ischemia and subsequently, typical cardiac symptoms (Al-Mallah et al., 2016). When combined with cardiovascular imaging, stress testing enables health professionals to visualize the heart and evaluate heart conditions. This medical practice allows physicians to rule out or validate evidence of heart diseases such CAD and provide early, effective treatments for patients.

A variety of imaging methods and modalities are used to assess CAD. Each technique has advantages and helps physicians understand how best to treat various aspects of heart diseases. Each technique also bears limitations, which may discourage its use in clinical practice. While the worldwide gold standard for diagnostic assessments of CAD is performed through anatomical or functional invasive methods with coronary angiography, these invasive procedures are costly and carry important risks for procedural complications (Tavakol et al, 2012). Thus, clinical guidelines and cost-effectiveness studies have encouraged the use of non-invasive imaging techniques to examine physiological signs of CAD to prevent unnecessary the use of invasive coronary angiography (ICA) procedures (Mancini et al., 2014; Campbell et al., 2014). Non-invasive cardiovascular imaging allows examining physiological signs of cardiovascular disease while preventing unnecessary invasive procedures (Kristensen et al., 2014). In many cases, non-invasive tests can be used to screen patients who may need to undergo further invasive treatments such as coronary artery bypass surgery or percutaneous coronary interventions. Most common advanced cardiovascular diagnostic tests used for diagnosing CAD are performed using medical ultrasound, nuclear medicine, computed tomography and magnetic resonance imaging (figure 1) (Ladapo et al., 2014; Mordi et al., 2017; Siontis et al., 2018).

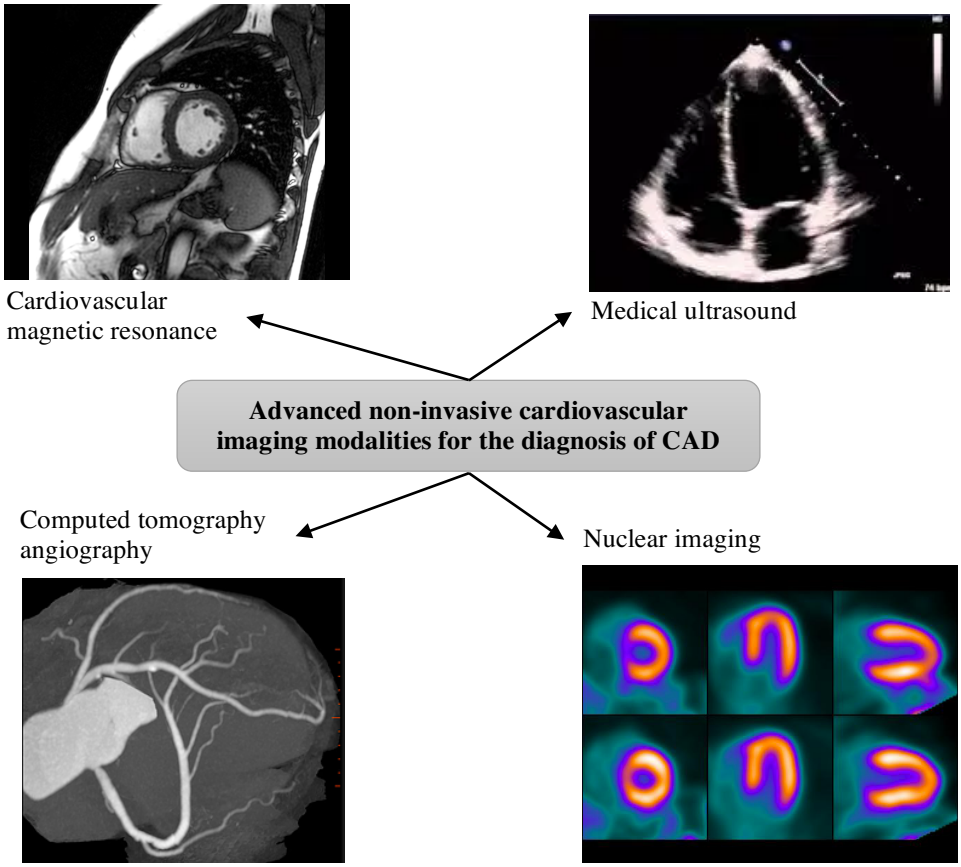

Figure 1. Advanced non-invasive cardiovascular imaging modalities for the diagnosis of CAD.

2.1.1. Cardiovascular Magnetic Resonance

Cardiovascular magnetic resonance (CMR) is a medical imaging technique that makes use of magnetic resonance imaging (MRI) to form detailed images of the heart (Botnar & Makowski, 2014). An MRI is a scanner in which a superconducting magnet produces a powerful external magnetic field of typically between 1.5 and 3 Tesla. This magnetic field is not completely uniform and contains small variations in field strength depending on the position within the magnetic field. These variations allow the position of nuclei in hydrogen atoms to be mapped. Electromagnetic energy is transmitted from a coil to the nuclei at a specific resonant frequency to excite them to a higher energy state. The net magnetic moment in this higher energy state moves out of the direction of an external magnetic field. As this surplus of energy decays back to a lower energy state, this energy is released as an electromagnetic wave, which is detected by an aerial or body coil. Having

different magnetic pulses offers the possibility to perform a variety of images with different structures of the body. The measured frequency is contingent to the local field strength to allow the intensity and spatial location of the wave to be mapped. Because different types of tissues return to their lower energy states at different rates, they can easily be differentiated. The received signal is then reconstructed using a complex mathematical algorithm and powerful computing to give an MRI image (Heatlie & Pointon, 2004). Major manufactures have developed simple automated user interfaces to compensate for the complexity of the technique. In combination with software companies who simplify the analysis, MRI is increasingly becoming an automated process that provides advanced data (Bertrand et al., 2017). Depending on the position of the patient within the scanner and the technologist's commands, different tissues and organs can be imaged. Figure 2 displays an image of a typical MRI scanner.

Figure 2. MRI scanner from starsappeal.org.

The common advantages of CMR include the use of non-ionizing radiation, it is considered as the gold standard for the non-invasive assessment of ventricle mass and function, it can assess the heart in any plane, and it offers viability assessment and the evaluation of valves and extra-cardiac structures. Limitations associated with CMR include its high costs, limited expertise, cannot be performed in patients with claustrophobia or renal impairment, image quality may be degraded by arrhythmia/tachycardia, and it commonly involves a relatively lengthy examination duration (Mordi et al., 2017; Danad et al., 2017).

2.1.1.1. Stress Perfusion CMR

In CMR imaging procedures, patients are typically asked to lie down within a scanner which surrounds most of their body while images are acquired. To examine CAD, the most common technique involves a pharmacological procedure in which a vasodilator agent is injected intravenously to trigger a response in the coronary perfusion beds, which, when compared to a baseline scan, may identify areas of impaired perfusion within the myocardium. Vasodilator agents commonly used in clinical settings include non-selective, such as adenosine, and selective adenosine agonists, such as dobutamine (Zoghbi & Iskandrian, 2012). Adenosine is a common ribonucleoside comprised of adenine bound to ribose, with vasodilatory, antiarrhythmic and analgesic activities frequently used in CMR clinical settings (Costa & Biaggioni, 1998). Its phosphorylated forms play roles in cellular energy transfer, signal transduction and the synthesis of RNA. This drug was initially used as an antiarrhythmic agent, to treat several forms of supraventricular tachycardia that do not improve with standard vagal stimulation (AHSF, 2017). adenosine can also be used as a metabolic drug endogenously released during hypoxia to acts as a vasodilator in the microvasculature (Pijls & De Bruyne, 2013). When injected as pharmacological agent during CMR, Adenosine's mechanism causes a blocking of calcium channels and an impediment to smooth muscle contraction which induces a stress response. Usual these stress tests in CMR require intravenous doses of adenosine as high as 140 micrograms/kg/min over 4 to 5 minutes, which consequently provoke an arterial pressure decrease of 6 +/- 7 mm Hg, and heart rate increase of 24 +/- 14 beats/minutes (Wilson et al., 1990).

With respect to its clinical use for diagnostic purposes, adenosine and its agonists have limitations: While generally considered safe, patients report side effects such as transient chest pain, irregular heartbeat, dizziness, flushing, and breathing difficulties in 90% of cases, in addition to putting patients to chance of serious complications such as heart attack, and recently the US food and drug administration released a warning due to adenosine as a rare (0.1%), but serious risk for complications such as heart attack or death (FDA, 2014). These danger warnings also included acute oral noxiousness, its germ cell mutagenicity, and its reproductive toxicity (IMS, 2010;

DailyMed, 2011). Adenosine infusion can cause arrhythmia and thus the presence of a trained health professional during infusion is required. It is contraindicated in patients with second or third degree AV block and sinus node disease, and should also be avoided in patients with known obstructive lung disease. Furthermore, the short half-life and variable response to adenosine may make it difficult to verify that an adequate level of adenosine is reached in the coronary vasculature, especially in patients with low cardiac output where the long transit time between the peripheral injection site and the myocardium may lead to its inactivation. Importantly, the use of adenosine adds significant costs to the diagnostic procedure. In Canada, a single pharmacological dose costs over $100 per patient and, as mentioned, to prevent resulting arrhythmia or bronchospasm, clinical practice requires a trained physician to be present during the agent's administration, which carries important costs (Iglehart, 2009).

2.1.1.2. Breathing Maneuver-Enhanced CMR

Previous research has shown that breathing manoeuvers, i.e. hyperventilation and long breath-holds, can elicit significant changes of cerebral and coronary perfusion, largely induced by the vasodilatory effects of blood carbon dioxide, which increases with apnea and decreases with hyperventilation (Guensch et al., 2013). While most imaging methods do not have sufficient temporal or spatial resolution to monitor these changes, breathing-induced changes of myocardial oxygenation by oxygenation-sensitive cardiac magnetic resonance (breathing maneuver-enhanced/b-CMR) allows for monitoring changes of myocardial oxygenation, and represents an alternative to adenosine infusion (Kramer et al., 2013). In both an animal model and healthy volunteers, it has recently been shown that b-CMR can also track changes of myocardial oxygenation during breathing maneuvers (Guensch et al., 2013; Fischer et al., 2016; Fischer et al., 2018) which could be induced by long breath-holds and hyperventilation. As the majority of myocardial functional imaging is performed to detect inducible ischemia, oxygenation-sensitive imaging is a direct marker for assessing myocardial oxygenation (El Aidi et al., 2014). This is an important feature because it offers a clearer picture about whether myocardial oxygenation is compromised or not, independently of changes in blood supply. Prior to its first application for cardiac imaging about 15 years ago, OS sequences were used in brain imaging (Ogawa et al., 1990;

Ogawa et al., 1990). Since the early 1990's, numerous studies have assessed the utility of the technique with numerous animal and human reviews describing the developing clinical applications (Matthews, 2006; Friedrich & Karamitsos, 2013). In order to detect myocardial oxygenation and accurately localize perfusion deficits with b-CMR, pharmacological agents such as adenosine are widely used because they can induce a vasoactive response. The stimulation caused by these agents can create hyperemia for the assessment of the myocardial oxygenation reserve, which increases measurement precision and sensitivity (Guensch et al., 2014). However, these pharmacological techniques are very costly, require the physical presence of a cardiologist, and may produce discomfort and cause unpleasant side effects (Polad & Wilson, 2002; Fischer et al., 2016). Early research has shown it is now possible to replace these pharmacological agents with breathing maneuvers (Guensch et al., 2013; Friedrich & Karamitsos, 2013; Fischer et al., 2016; Fisher et al., 2018). Breathing maneuvers involving a period of hyperventilation followed by a long breath-hold leads to coronary vasodilatation and therefore to a change of myocardial oxygenation that is detected by b-CMR (Klocke & Rahn, 1959; Parkes, 2006; Guensch et al., 2013). In both the heart and brain a variety of breathing patterns have been assessed. One of the disadvantages of CMR though, it the majority of images need to be obtained in a breath-hold, thus the breathing maneuvers must remain prompt and feasible to be completed within a breath-hold,. Thus, Guensch (2014) and Fischer (2015) assessed different combinations of breathing maneuvers in healthy participants. Their results showed that combined maneuvers of hyperventilation, which leads to vasoconstriction, and breath-hold, which leads to vasodilatation, created a greater range of vasomotion and had the strongest impact on the heart (Parkes et al., 2006; Fischer et al., 2016). The b-CMR technique is currently being tested further in clinical research. In order to ensure appropriate cooperation, research participants typically undergo a brief training on breathing maneuvers. The breathing procedure goes as follow: 1) the participant breathes at a normal rate and makes an end-expiration breath-hold of 3 to 10 seconds, 2) the participant hyperventilates for 60 seconds breathing at a deep and rapid pace in sync with the clicks of a 60-beats/minute metronome, and 3) at 60s into the hyperventilation the participant is instructed to take one breath after which they conduct an end-expiration breath-hold that is maintained for as long as comfortable. CMR images are acquired continuously before hyperventilation and throughout the breath-hold until patients resume regular chest movement indicating the end of the breath-hold. The response is calculated by the percent change in signal intensity between the baseline image

prior to hyperventilation and the first image of the breath-hold (Fischer et al., 2016; Bertrand et al., 2017). The complete b-CMR protocol is typically completed within 30 minutes.

Although the breathing manoeuvers technique is relatively recent and has not been implemented in clinical settings, it shows promising benefits in the diagnostic workup of CAD. Recent research has shown that patients who performed breathing manoeuvers in CMR reported mild side effects such as brief tingling in the fingers, dizziness and dry mouth, which disappeared after the manoeuvers and normal breathing recommenced. By reducing the examination time, avoiding the costs associated with the price of pharmacological agents and the mandatory presence of a trained health professional, the breathing manoeuver technique presents a safe, simple, and cost-effective alternative that does not require any injections and gives control to the participant thus presenting a possible improvement to the patient experience (Fischer et al., 2018).

2.1.2. Medical Ultrasound

Medical ultrasound is a diagnostic imaging technique based on the application of ultrasound that makes use of sound waves with high frequencies to visualize organs in the body. The sound frequencies in ultrasound medical devices operate with frequencies of 2 megahertz and higher. The wavelength used will depend on the acoustic impedances of different body tissues and organs that are examined. For example, heart tissues have an acoustic impedance of 1.64 gigarayls while bone tissues have an acoustic impedance of up to 7.8 gigarayls, which require higher frequencies. This technique has been used in clinical settings since the late 1970s and has become routinely used in the diagnosis, management, and follow-up of patients with any suspected or known heart diseases. It is one of the most widely used cardiovascular tests in diagnostic cardiology and can provide a range of useful information, including the dimensions of the heart, its pumping capacity, and a description of tissue damage (Azhari, 2010). A cardiac ultrasound can also be used to provide health professional with various estimates of the heart function, such as a calculation of the cardiac output, diastolic function and ejection fraction. Figure 3 displays an image of a typical ultrasound device.

Figure 3. Ultrasound device from news-medical.net.

Overall, medical ultrasound does not include ionizing radiation, include extensive long-term data, are relatively fast to perform, offers information on LV function and valves, and can easily be assessed using different types of procedures such as exercise and pharmacological agents. However, exercise is limited by patient's physical capacity, despite the use of contrast, image quality remains suboptimal, and often results in false positives (Mordi et al., 2017; Danad et al., 2017). In addition, ultrasounds do provide information about tissue characterization, and it is limited primarily to functional and anatomical assessments. The diagnostic accuracy for identifying CAD using ultrasound involves a 69% sensitivity and an 84% specificity (Takx et al., 2015).

2.1.2.1. Exercise Stress Test

The most common type of heart ultrasound for diagnosing CAD is referred as a stress echocardiogram. This technique examines and compares the patient's heart function at rest and in action (at stress). The patient's heart at rest is evaluated with an echocardiogram at the beginning of the appointment and the patient is then required to undergo a standard treadmill test, where the speed and inclination of the treadmill are gradually increased. At each interval, the physician is

attentive to any changes in the patient's symptoms such as chest pain or shortness of breath. The patient remains on the treadmill until the physician indicates test termination, usually when the patient becomes symptomatic or reaches a target heart rate. The patient then quickly returns to the examination table and receives another echocardiogram for the physician to evaluate their heart at stress. The changes between the heart at rest and at stress are then compared to estimate the extent of CAD (Silva et al., 2015; Lancellotti et al., 2017).

2.1.2.2. Pharmacologically Induced Stress Test

For patients who are unable to exercise, pharmacological agents similar to those used in CMR can be used as alternatives to measure physiological signs of cardiovascular effort. These drugs elicit an increase of cardiac output and a subsequent rise in myocardial oxygenation demand, similar to that resulting from exercise (Liu et al., 2016; Thomas et al., 2017). Vasodilators do not apply physical cardiac stress but rather expose a regional lack of vasodilatory capacity, leading to relative differences in myocardial perfusion (Karnabi & Hendel, 2017). For example, through specific activation of the A2A receptor, agents like adenosine may induce direct coronary arteriolar vasodilation, which may result in an increase in myocardial blood flow in patients. This leads to an attenuated hyperemic response in myocardial regions supplied by stenotic coronary arteries. Therefore, depending on the extent of CAD, a relative flow heterogeneity is induced resembling that following stress induced by physical activity (Gibbons et al., 2002). In both the exercise and pharmacological techniques patients are exposed side effects such as transient chest pain, irregular heartbeat, dizziness, flushing, and breathing difficulties, in addition to being exposed to a 0.1% (1 in 1,000) risk of serious complications such as heart attack.

2.1.3. Computed Tomography Angiography

Computed tomography (CT) imaging is based on the variable absorption of x-rays by different tissues. In contrast to conventional x-ray imaging, CT provides a different form of imaging known as cross-sectional imaging that involves a complex range of images of the

anatomy. Similar to CMR, CT requires the use of a motorized table and a scanner in which the patient lies down to acquire images of the body. As the patient passes through the scanner, a source of x-rays rotates around the inside of a circular opening which produces a thin beam of radiation used to irradiate a section of the body. A typical examination requires several phases that are each made up of 10 to 50 rotations of the x-ray tube around the patient in coordination with the motorized table moving through the scanner. The patient then receives an injection of a contrast agent to facilitate visualization of the vascular structure while detectors record the section of the body being irradiated (Hsieh, 2009). By compiling the images of different sections made during one complete rotation, data are sent to a computer to construct a cross-sectional image of the internal organs and tissues examined.

Coronary CT angiography (CTA) is a non-invasive imaging technique using CT principles and primarily used for imaging of the coronary arteries and to define the presence or absence of CAD. Unlike other non-invasive tests, CTA does not require rest and stress procedures to diagnose CAD. Instead, CTA provides a detailed examination of fatty and calcium deposits and narrowing in the coronary arteries. However, this imaging technique carries potential risks due to exposure to ionizing radiation (Halpern, 2010). When imaging coronary arteries, a variety of complex post-processing techniques are used for reconstruction following image acquisition. This is mainly due to the adjustments or gating performed to compensate for cardiac motion which affects image quality. Because of this need for gating, radiation exposure from this procedure can be significant. A single CTA can expose patients to a radiation dose equivalent to having over 150 chest x-rays (Hausleiter et al., 2009). The increase in use throughout the last decade of this procedure has raised concern among physicians and patients about the potentially harmful effects of radiation exposure from cardiac CTA (Douglas et al., 2006; Einstein et al., 2014). Therapeutic doses of radiation are known to induce a complex network of signal transduction pathways that affect gene expression and protein structure (Marchetti et al., 2006), which may lead to programmed cell death, cell cycle arrest or progression, and deoxyribonucleic acid (DNA) repair to minimize the risk of mutagenesis. Whether similar damages and an activation of these biological pathways are caused by radiation doses from medical imaging tests is less certain and the long-term effects of radiation exposition due to medical imaging remain unclear (uz Zaman et al., 2016). It was reported that patients undergoing cardiac CTA have evidence of DNA damage in T lymphocytes, which may be

associated with cell death, and interfere in the activation of genes involved in cell repair and apoptosis (Nguyen et al., 2015). Literature shows that CTA has a moderate to high diagnostic accuracy (Neglia et al., 2015; Lee et al., 2015; Balfour et al., 2017). CTA does not involve a vasoactive agent inducing a stress response, but it requires the injection of radioactive pharmaceutical material (Clark & Gunn, 2017). Figure 4 displays an image of a typical CT scanner.

Figure 4. CT scanner from insidertradings.org.

In sum, CTA provides precise anatomical detail, it is particularly useful as a rule-out test due to high sensitivity and low false-negative rate, and it offers information on function and valves it is readily available on most modern CT scanners. Nonetheless, this modality involves exposure to ionizing radiation, does not provide ventricular functional assessment unless retrospective gating is used with a consequent increase in radiation dose, image quality is very dependent on optimization of patient factors (heart rate/rhythm, breath holding), and musts be used with caution in patients with renal impairment (Mordi et al., 2017; Danad et al., 2017).

2.1.4. Nuclear Imaging

Like CTA and CMR, nuclear imaging techniques involve the use of a scanner, and requires patients to be injected with radiopharmaceuticals that emit gamma rays in a targeted part of the body. The scanner detects radiopharmaceuticals using a gamma camera while the patient lays in

the scanner, which allows seeing the inside of the body without requiring invasive procedures. Like CTA, patients undergoing nuclear imaging are exposed to doses of radiation, but unlike in CTA, which sends radiations through the body, nuclear imaging uses radiations in radiopharmaceuticals within the body. This is useful to determine the cause of a medical problem based on the organ's molecular function, whereas other diagnostic tests determine the presence of disease based on physiology or anatomy. Radiopharmaceuticals carry small amounts of radioactivity and are normally broken down by kidneys within 24 to 72 hours (Webb & Kagadis, 2003). Figure 5 displays an image of a typical nuclear imaging scanner.

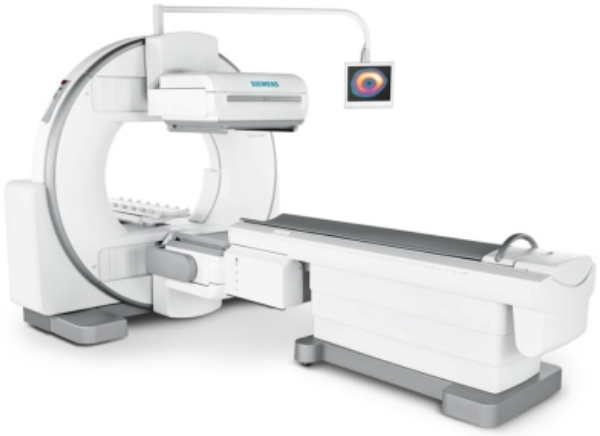

Figure 5. Nuclear imaging scanner from frhg.org.

Generally, advantages of nuclear imaging tests include extensive long-term prognostic data, offers functional information, and has potential to provide anatomical information in addition to functional ischemia assessment. However, it requires exposure to ionizing radiation, involves difficulty in the assessment of balanced ischemia, and includes chances of false positives in patients with left bundle branch block due to partial volume effects (Mordi et al., 2017; Danad et al., 2017).

2.1.4.1. Positron Emission Tomography

A positron emission tomography (PET) scan is a nuclear medicine imaging test that a uses a radiopharmaceutical made up of a radioactive isotope attached to a radioactive sugar, usually glucose, water or ammonia, to create images of body function and metabolism. This allows a precise evaluation of the biological function of cells and organs. In cardiovascular imaging, the radiopharmaceutical (usually rubidium-82 or ammonia-13) concentrates in the myocardial tissues and is detected by the PET scanner. Patterns of radioactivity from the radiopharmaceutical are then pick up by detectors and processed by a computer to produce 3-dimensional color images of the area being scanned (Saha, 2015). PET myocardial perfusion imaging scans can be used to diagnose CAD by differentiating healthy and affected areas of the myocardium. By tracking radiopharmaceuticals in myocardial tissues, the PET scan shows whether blood flow is reduced due to narrowed arteries. Compared to other cardiovascular imaging procedures PET scans are lengthy and expensive. Complete PET myocardial perfusion imaging exams last about an hour and may cost approximately 2 000 Canadian dollars (Martinuk & Meyer, 2013). Similar to other stress tests, images need to be taken at rest and at stress. However, in PET imaging, both sets of images require separate injections of radiopharmaceuticals, in addition to the vasodilator agents used to simulate exercise. As previously described, these radiopharmaceuticals and vasodilator agents may carry important risks and side effects. Literature showed that PET myocardial perfusion imaging has high diagnostic accuracy (Neglia et al., 2015; Balfour et al., 2017).

2.1.4.2. Single Photon Emission Computed Tomography

A cardiovascular single photon emission computed tomography (SPECT) is a non-invasive nuclear imaging test of the heart also used to diagnose CAD. Like PET scans, SPECT myocardial perfusion imaging scans track radiopharmaceuticals (usually technetium-99m or thallium-201) in the myocardium to measure blood flow and the narrowing of coronary arteries. SPECT examinations are very lengthy (often over an hour), but SPECT scanners are less expensive than PET scanners. Typical SPECT myocardial perfusion examinations are relatively not costly (Lee et al., 2015). SPECT typically has more artifacts and lower image quality than PET, and the diagnostic accuracy of SPECT is therefore usually lower than PET. Literature has shown that SPECT MPI has a relatively low diagnostic accuracy (Neglia et al., 2015; Takx et al., 2015).

In sum, medical ultrasound, nuclear medicine, computed tomography and magnetic resonance imaging have been described as common cardiovascular imaging modalities used for diagnosing CAD in cardiac patients (Ladapo et al., 2014; Mordi et al., 2017; Siontis et al., 2018). Within each modality, different tests are available and present characteristics with their own strengths and limitations. Ordering these clinical imaging tests is a complex process that requires professional regulations.

2.1.5. Ordering Cardiovascular Diagnostic Imaging Tests

In healthcare, physicians are responsible for determining likely health-related diagnoses. They perform comprehensive physical examinations and use necessary medical tools to allow them to make evidence-based observations and diagnoses for both acute and chronic conditions. Diagnosis is an important part of a physician's expertise in medical practice and is based on detailed assessment training and skills. It is a core cognitive and medical competency, based on knowledge, experience, and judgment. For patients reporting acute or chronic cardiovascular symptoms such as chest pain, irregular heartbeats, shortness of breath and fatigue, physicians will likely suspect the presence of heart disease such as CAD (Hendel et al., 2006). Ordering a cardiovascular imaging test for these patients will offer detailed anatomical, molecular or physiological information that will typically allow physicians to make a diagnosis. This diagnosis will be used to choose a treatment or medical workup that will maximize the health prognosis and quality of life of patients. In Canada, family physicians and cardiologists are most often responsible for ordering cardiovascular imaging tests for patients with suspected CAD (Health Council of Canada, 2010).

2.1.5.1. Family Medicine and Diagnostic Imaging

Family physicians are typically considered as primary caregivers and often constitute the first point of contact for patients seeking healthcare (Allan, 2016). In Canada, they play a central

role in the diagnostic of diseases and management of public resources, which has effects not only on patients but also on the entire healthcare system (McMurchy, 2009). Because of their decision-making authority, they are considered as the gatekeepers of healthcare, ensuring the appropriate transition of patients to health services (Canadian Medical Residency Guide, 2011). With the increases in investments for diagnostic imaging in Canada and the improved availability of screening tools, family physicians have been taking on a larger role in ordering cardiovascular diagnostic tests (Health Council of Canada, 2010). This may be explained because they more frequently follow aging patients with chronic diseases such as diabetes, hypertension and other chronic cardiovascular conditions. Concurrently, they are encouraged to contribute to public policies by making appropriate use of public resources and support cost containment (Allan, 2016).

In sum, family physicians are expected to ensure that patients receive quality care in a timely manner and to reduce unnecessary costs to the health care system (Health Council of Canada, 2010). They play an important role in ordering diagnostic imaging while having to make appropriate decisions regarding the use of diagnostic tests.

2.1.5.2. Cardiology and Diagnostic Imaging

Cardiologists are medical specialists in the field of cardiology and in the diagnosis and management of all aspects of cardiovascular disease. They usually focus on the prevention, diagnosis, and management of disorders of the cardiovascular system. Because of their specialization, many family physicians refer their patients with suspected heart conditions to cardiologists. Cardiologists can follow any patients with suspected or diagnosed cardiovascular diseases. Part of their specialization includes an extensive training in choosing appropriate imaging methods for diagnosing cardiovascular disease and decide upon the recommended treatment options. Although family physicians generally constitute the first line of health care for cardiac patients, they often refer their patients with mild to severe cardiovascular conditions to cardiologists to ensure expert and advanced cardiac interventions. Although cardiologists have developed an expertise in the diagnosis and management of heart conditions, they are encouraged to comply with clinical recommendations and to consider appropriate use criteria.

2.1.6. Appropriate Use Criteria

Important concerns about overuse of invasive diagnostic imaging techniques and subsequent implications for patient safety have repeatedly been expressed (Friedrich & Karamitsos, 2013). Expenditures in healthcare related to invasive imaging are increasing dramatically, especially in the field of cardiovascular disease (Health Council of Canada, 2010). To assess the extent of coronary stenosis, diagnostic cardiac catheterization performed with invasive coronary angiography (ICA) is currently widely used as gold standard for diagnosing CAD. As mentioned previously, due to the high-costs and the risks for acute surgical complications associated with ICA, the concerns raised by the overuse of this invasive surgical diagnostic method affected its sustainability (Karamitsos et al., 2009). In this context, complementary methods were implemented to assess and monitor the appropriateness of the usage of invasive imaging practices with an emphasis on making a more realistic use of healthcare resources. As such, the development of appropriate use criteria (AUC) has been globally implemented in public clinical settings (Belardinelli et al., 1989). For diagnostic characterization using ICA, AUC are thus used for measuring the appropriateness of surgical procedures. These methods commonly involve a panel process that used assessments of benefits versus risks to rate all potential indications for a procedure as appropriate, uncertain, or inappropriate. AUC are currently at the heart of high-quality care and have been important in healthcare research (Guensch et al., 2013). For a surgical intervention to be justified, defining it as appropriate or not appropriate has been reported to offer insights about its potential benefits and harm (Belardinelli et al., 1989). Figure 6 displays an example of multimodality appropriate use criteria for the detection and risk assessment of stable ischemic heart disease in symptomatic cardiac patients extracted from Wolk and colleagues (2013).

	Indication Text	Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
1.	• Low pre-test probability of CAD • ECG interpretable AND able to exercise	A	R	M	R	R	R	R
2.	• Low pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	M	R	M	R
3.	• Intermediate pre-test probability of CAD • ECG interpretable AND able to exercise	A	A	A	M	R	M	R
4.	• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	A	R	A	M
5.	• High pre-test probability of CAD ECG interpretable AND able to exercise	M	A	A	A	R	M	A
6.	• High pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	A	R	M	A

Appropriate Use Key: A = Appropriate; M = May Be Appropriate; R = Rarely Appropriate.
A = Appropriate; CAD = coronary artery disease; CCTA = coronary computed tomography angiography; CMR = cardiac magnetic resonance; ECG = electrocardiogram; Echo = echocardiography; M = May Be Appropriate; R = Rarely Appropriate; RNI = radionuclide imaging.

Figure 6. Example of AUC in symptomatic cardiac patients from Work et al., (2013).

In most instances, the previously described non-invasive cardiovascular imaging techniques are used as safer diagnostic tests to screen patients for further treatments, including ICA. Evidence of the AUC for validating this approach has been supported academically, and the use of AUC for guiding ICA and subsequent revascularization has been associated with a reduction in mortality (Biaggioni et al., 1991). However, interventional cardiology guidelines and AUC for coronary revascularization exclude considerations related to patient preference. Rather, physicians typically choose evidence-based treatment strategies for their patients, without engaging in a discussion about what would be the best alternative for them. Current AUC do not account for personal contexts and perspectives, and usually disregard the fundamental role of patient preference as to which treatment strategy should be taken (Kristensen et al., 2014). Recognizing this malpractice, guidelines for the diagnosis and management of patients with stable ischemic heart disease documented the importance patient-centered research to help inform referring physicians about treatment strategies that are preferred by patients (Fihn et al. 2012; Nishimura et al., 2014; Mancini et al., 2014).

2.2. PATIENT-CENTERED MEDICINE

As expressed by Klein (2003): “A patient brings a unique context and perspective to medical decisions that the physician cannot emulate: the choices made will impact the patient forever” (p. 1).

The medical approach to human health has undergone several changes in the last century, and especially for what applies to the doctor-patient relationship (Kaba & Sooriakumaran, 2007). Potter & McKinlay (2005) defined this relationship between the patient and the doctor as a system of communication and a rapport of ethics surrounding the treatment process, in which each part of the dyad has a significant and distinctive role. Historically, medicine has been largely centered on efficiency, outcomes, and physicians, but more recently, patients’ perspectives have been increasingly considered for clinical decision-making. In the patient-centered approach to medicine, important considerations are given to patient preference (Baker, 2001; Brodney et al., 2016). Involving patients’ needs and wants to clinical decision-making is an approach that has long been reported to lead to higher quality of care and health outcomes (Frosh et Kaplan, 1999). In this context, healthcare reforms have repeatedly emphasized the need to account for patients’ preferences when choosing treatments (Xu & Wells, 2016). This type of practice is now central and in accordance with the ethical principle of autonomy which indicates that healthcare providers are obliged to solicit and respect the patient’s preferences about the choice of therapy (Kasper et al., 1992). A positive doctor-patient relationship is said to be fundamental to the practice of healthcare and is key for the delivery of successful identification of diagnoses and treatment of diseases (Côté & Leclère, 2000; Herbert, 2002).

2.2.1. Evolution of the Doctor-Patient Relationships

2.2.1.1. Paternal model of healthcare

As explained by Kaba and Sooriakumaran (2007), the relationship between the curer and the cured has undergone several distinctive transitions and phases throughout the last decades. They reported that, in the 1990s, the doctor-patient relationship was essentially one of a compliant

patient seeking help indubitably and silently from his doctor who gave him prescriptions and directives. Accordingly, patients did not actively participate in this one-way process to healthcare; from the figurative paternal figure (the doctor) to the passive patient. This paternal model if care was traditionally widely accepted as the doctor being the one that knew, and the one that possessed the skills to choose the appropriate treatments that were most likely to reestablish the patient's health. The paternal model of medicine was fundamentally asymmetrical and influenced the doctor-patient relationship in such a way that many started to question this model. Hence, the doctor-patient relationships became more balanced over the years, and more patients requested more control over the decisions regarding their medical workup, which became gradually more mutual.

The rise of the Internet and self-diagnosis has also been reported to influence this shift in medical paradigm. Akerkar and Bichile (2004) studied the impact of the rise of the Internet on the medical field. The author referred to the "e-patient revolution" to explain the increasing availability of online information pertaining to medicine and health. This implied that as patients did not always need to see a doctor face-to-face when in need of information and made them more autonomous. The author also argued that the accessible online information helped patients detecting their illness faster, making self-diagnoses, feeling more empowered, and moving from "blind trust" to "informed trust" in their doctor. Patients did not have to passively follow their physician's recommendations like they did in the paternal model of care and could be more easily be involved in the treatment process. Yet, it was also reported in this study that less reliability in treatments, more erroneous diagnoses, and less human interaction could result from online information and self-diagnoses. Similarly, Broom (2005) investigated the possible implications of Internet-informed patients on the doctor-patient relationship and health outcomes. The author reported that, in some cases, the awareness of the patient, rather than their ignorance, about the medical treatment process did not improve their condition.

2.2.1.2. Patient-centered model

Reviewing the 20th-century theoretical conceptions of the doctor-patient relationship, Potter and McKinlay (2005) argued that both, doctors and the patients need to be involved in the curative process of medicine in order to make it as effective as possible. These authors suggested that patients need to be more educated about how to use their time efficiently with their doctor and that physicians should improve their communication with patients to better educate them about their health. This approach favored a progression from the paternal model to a more mutually-based relationship. Being increasingly aware of their patients' desires for a more supportive medical approach, physicians put more and more importance to their patients' perspective and preferences in the healing process (Beckman et al., 1994; Hahn et al., 1994; Candib & Ferguson, 2002). This more caring paradigm was labeled "patient-centered care" (PCC), implying that the patient's physical and psychological comfort was to be accounted for by a caring doctor while empowering patients to take on an active role in their own health (Reynolds, 2009). In this context, a report on the status of health care in the United States identified 6 characteristics of an effective healthcare system: The system should be 1) safe, 2) effective, 3) patient-centered, 4) timely, 5) efficient, and 6) equitable (Ross et al., 2001). PCC was thus described as "respectful of and responsive to individual patient preferences, needs, and values and ensures that patient values guide all clinical decisions" (p. 1328).

The importance of considering patients' perspectives and preferences in clinical decisions have long been reported (Brennan & Strombom, 1998; Arora & McHorney, 2000; Say & Thompson, 2003; Joosten et al., 2008). Figure 7 shows the eight principles of PCC as reported by Harvard Medical School, where respect for patients' preferences was placed at the top of the pyramid. Research has shown that PCC has distinctive benefits to the quality of treatment and to the doctor-patient relationship (Oates et al., 2000). When measuring the physiological effects of patients treated in positive environments in which the doctor-patient relationships were optimal, Adler (2002) reported patients had improved responses to their healthcare. He reported that patients treated in an empathic therapeutic context exhibited a correlation of indicators of autonomic activity, which signaled a positive physiological response. This was explained by the experience of feeling cared for in a relationship could reduce the secretion of cortisol in patients. A relaxed psychological and physical state could facilitate the effectiveness of the treatments during medical interventions. In addition, Ferguson and Candib (2002) studied how language and

cultural differences between patients and their doctors could influence communication in the doctor-patient relationship. In their literature review, they reported that such differences highly affected the quality of the communication because visible minorities and those who were not fluent in English were less likely to engage in empathic relationships with their physicians. These studies effectively showed that the quality of the relationship between physicians and their patient had an effect at the individual level that is not negligible.

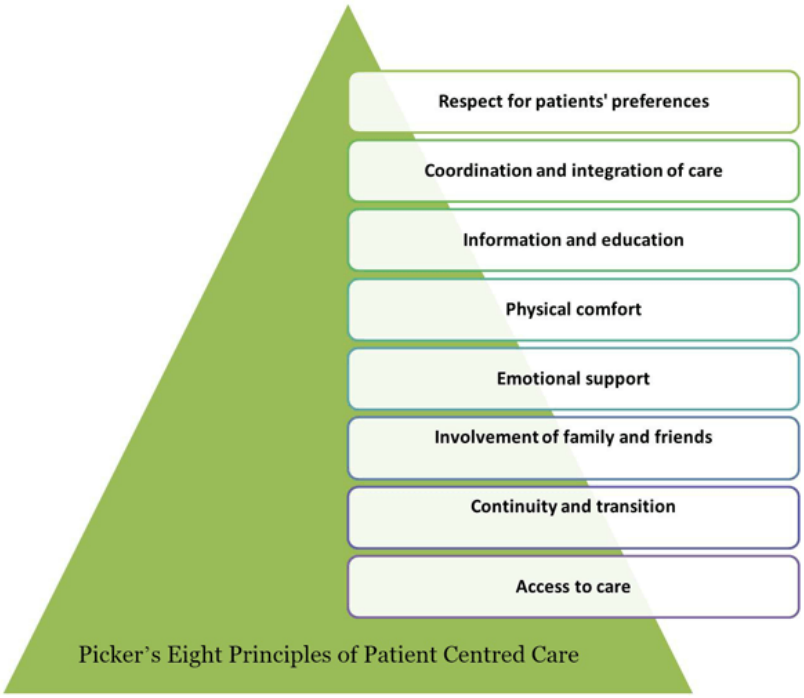

Figure 7. Eight principles of PCC highlighted in research conducted by Harvard Medical School.

Speedling and Rose (1985) claimed that encouraging patients to take an active role and being more personally engaged in their own healthcare can considerably increase the subjective and objective effectiveness of medical treatments. In shared decision-making, both patients and physicians are involved in clinical decision-making, and the best available evidence regarding treatment options to derive personalized estimates of risks and benefits for each choice should be discussed. It involves a process of education and interactions with an aim to deliberate and reach consensus. This process has been shown to improve knowledge, reduce decisional conflict, and increased patient involvement in shared decision-making (Hess et al., 2015). Informed consent is another key aspect of shared decision-making. As specified by the American College of Cardiology (2015):

> The underlying basis for the doctrine of informed consent is the patient's right to self-determination - the patient's right to make an informed choice on whether to choose or decline a medical procedure (p. 5).

Appropriate communication between the physician and the patient is thus required to practice appropriate informed consent, particularly as limited knowledge may restrict patients' ability to communicate confidently with physicians and thereby to engage in shared decision-making (Ha & Longnecker, 2010; van Empel et al., 2010). Patient and physician communication is a complex process, which is essential for high-quality care delivery and directly affecting patient satisfaction and adherence to treatment (Martin et al., 2005). A seminal study from Gafni and colleagues discussed two treatment decision-making models: "1) the physician as a perfect agent for the patient, and; 2) the informed treatment decision-making models. Authors argued that both models generally resulted in the same constructive outcomes. It has been shown to allow patients to uncover information essential for an accurate diagnosis of their problems, to enable physicians to have a better understanding of their patients' needs and, ultimately, to lead to better health outcomes (Kee et al. 2017). Considering these findings, modern medicine has focused on identifying means to improve patient and physician communication. For example, recent studies have investigated and compared different physician strategies for communicating diagnostic uncertainty (Cousin et al., 2013; Bhise et al., 2018).

2.2.1.2.1. From the Patient's Perspective

As patient-centered research emerged, researchers aimed to explain and measure factors influencing doctor-patient relationships from the patient's perspective (Stewart et al., 1979; Kaba & Sooriakumaran, 2006; Kearley & Freeman, 2001). Delbanco (1992) studied interactions between doctors and their patients and isolated recurrent themes to explain what constitutes a positive doctor-patient relationship: "1) respect for patient's values, preferences, and expressed needs; 2) communication and education; 3) coordination and integration of care; 4) physical comfort; 5) emotional support and alleviation of fears and anxieties; 6) involvement of family and

friends, and; 7) continuity and transition" (p. 16). By combining and reviewing each of these themes in the treatment process, authors emphasized the relationship between patients and their doctors could be strengthened. Similarly, a consensus statement developed by Makoul and representatives from medical education and professional organizations (2001) reported seven essential communication tasks: "1) build the doctor-patient relationship; 2) open the discussion; 3) gather information; 4) understand the patient's perspective; 5) share information; 6) reach agreement on problems and plans; and 7) provide closure" (p. 209). Beckman et al. (1994) used a descriptive series review of 67 lawsuits made by patients towards their doctors to examine the reasons explaining why patients were unhappy with their healthcare and suing. They reported that the relationship between the patients and their doctor played a central role in their decision for making a formal complaint. The main reasons justifying the lawsuits were found to be 1) deserting a patient; 2) devaluing a patient's view; 3) delivering information poorly, and; 4) failing to understand the patient's perspective. The authors concluded that accounting for patients' perspectives can improve the quality of the doctor-patient relationship, and thus prevent patient dissatisfaction and desire to sue their physician. Furthermore, Scott and Vick (2003) later examined what patients perceived to be the most important factors influencing their medical treatment satisfaction. Among several factors, patient satisfaction was most influenced by the quality of the communication between the doctor. More recently, researchers have focused on methods to facilitate doctor-patient communication (Epstein & Street, 2007; October et al., 2016; Fenton et al., 2017). Increasingly, clinicians' respect for patients has been subject to attention in the medical field. Physicians' recognition of the "unconditional value of patients as persons" has been associated with positive therapeutic outcomes (Beach et al., 2007; Flickinger et al., 2016). By endorsing this notion of respect, physicians would more likely consider patients' perspectives and preferences in aiming for improved clinical communication and decision-making (Tseng & Hicks, 2016).

2.2.1.2.2. From the Physician's Perspective

It was reported that patient satisfaction is an insufficient measure of the quality of the doctor-patient relationship and the views of physicians need to be considered as well (Speedling

and Rose, 1985). Using a quantitative approach, Kearley and Freeman (2001) studied the importance of the relationship between patients and general practitioners and showed that both groups rated the importance of having a positive doctor-patient relationship as "very valued". These results were especially true when applied to the cases of serious illness. Also reported from this study, patients were more likely to seek medical help when they perceived a more positive relationship with their doctor. However, more recent research has shown that physicians often underestimate the importance of patient-centeredness (van Empel et al., 2011). In 2003, Lings and colleagues published a qualitative study of the doctor-patient relationship in primary care reported three key factors in the doctor-patient relationships: 1) an asymmetry of perceptions on the two sides, 2) opposing the notion of a meeting of experts; the importance on both sides of 'liking'; and 3) the value set by both parties on development of trust. This study illustrated the complex and asymmetric nature of the doctor-patient partnership by showing that the lived experiences of patients and physicians differ but do not necessarily contradict each other. Being respected and feeling liked is also important to physicians, and can help in the development of trust in the doctor-patient relationship. May et al. (2004) investigated the ways in which the legitimacy of medical practices was organized in relation to chronic illness. They performed a comparative analysis of "1) the moral evaluation of the patient (and judgments about the legitimacy of symptom presentation); 2) the possibilities of disposal; and 3) doctors' empathic responses to the patient, in each of these clinical cases" (p. 61). They found that physicians would often modify their diagnosis and choice of treatment based on patients' social and psychological conditions, rather than operating only medical symptoms. To successfully follow a patient-centered approach to healthcare, physicians should make efforts to understand patients' current functioning and to be able to explain the prognosis and treatment options in a language that patients understand. Doing so in terms of their health status has been reported to improve the quality of communication and lay the foundation for shared decision-making (Epstein, R. M., & Street, R. L. (2011).

Research has demonstrated that physician and patient communication is critical to determine the best options considering patients' preferences (Kelley et al., 2014). Patient decision aids have even been developed to improve patient engagement in treatment and in screening decisions (Witteman et al., 2015; Stacey et al., 2017). Therefore, knowing that differentiated perceptions may reflect ineffective communication between the provider and the patient, it is

important to learn about factors that influence referring-physicians' preferences and decision-making (Mühlbacher & Nübling, 2011; Gunn et al., 2013). In addition, preference incompatibility in treatment decisions between patient and healthcare providers have been reported to lead to silent misdiagnosis, or preference misdiagnosis (Mulley et al., 2012). These findings show how the doctor-patient relationship in PCC can influence the choice of treatment, and consequently affect both the patients' and the doctors' perception of the healing process.

2.2.2. Patient-Centered Cardiovascular Imaging

Although this principle, in the setting of cardiovascular disease, has received only limited attention, the concept of shared decision-making is increasingly viewed as an approach to ensure patients remain involved in important decisions regarding their health. In cardiovascular imaging, reports of a lack of consideration to patient preference were common when ordering cardiovascular imaging tests (Spertus, 2008; Hess et al., 2012). In addition, Einstein and colleagues (2014) mentioned that:

> Cardiac imaging procedures have come under increasing scrutiny as a result of high utilization volume, concerns over inappropriate use, a lack of adherence to quality control, and the potential of cancer risks attributable to ionizing radiation exposure (p. 1480).

Similarly, the ACC and the AHA have jointly reported the importance of considering issues related to patient preference to influence the choice of tests or imaging procedures, and committed to develop a patient-centered approach to cardiovascular care (ACCF, 2009; Nishimura et al., 2014). The ACC (2012) specifically published a health policy statement focusing on PCC in cardiovascular medicine. Responsible for developing and implementing health policy statement policies and procedures, the ACC Foundation Clinical Quality Committee recommended the development of this statement to document the College's official position on PCC. The writing committee included a broad range of specialists and health advocates, including experts in patient adherence and patient education. While recognizing that PCC involves a recognition and respect of one's circumstances and decisions in healthcare, they reported that patient involvement cannot

be successful without the providing them with appropriate information, including the existence of alternatives with their respective positive and negative attributes. They added that allowing patients with a chronic cardiovascular disease to get involved in their own health requires them to understand their disease and the status of their condition. Authors referred to studies to support their stand on this issue. For example, Schattner et al. (2006) reported that receiving more information from the physician and being involved in decisions regarding their health was highly desired by cardiac patients. It was also reported that a large majority of patients wish to be told of all possible adverse effects related to their possible treatment alternatives (Walsh et al., 2012). Furthermore, Wagner et al. (2005) proposed that patient involvement needs to be improved through self-management, education, collaborative goal-setting, and treatment planning.

Yet, evidence has suggested that most patients with chronic disease do not receive adequate clinical information to support self-management and that many physicians fail to educate patients on important elements of their treatment (McGlynn et al., 2003; Tarn et al., 2006). Very often, however, patient preference remains firmly based on the referring physician's opinion (Lang et al., 2013). The quality of a radiological intervention may not be measured by the satisfaction or preferences of the referring physicians, but radiology is responsible for offering a service to patients, who are most commonly referred from these physicians (usually general practitioners and cardiologists) (Harris et al., 2017). As such, appreciating the service clinicians feel they require for safe and effective treatment for their patients is part of providing this service (Lindsay et al. 2011; Jensen et al., 2016). A review of literature comparing physicians' judgment to patient preferences reported that referring physicians play a central role in the decision of medical intervention to be conducted (Mühlbacher & Juhnke, 2013). This highlights the need for the referring physician to be well versed in the selection of the most appropriate cardiac imaging tests based on knowledge of the strengths and limitations of the individual modalities while accounting for patient preferences.

To summarize, successful PCC is an important foundation for improving patients' satisfaction with healthcare. The healthcare system increasingly focuses on its ability to provide patients with the respect, attention, and evidence-based treatment following their needs and wants. Patient-centered medicine tends measures these outcomes by investing in shared decision-making

to support the investment of resources in aiming to optimize the outcomes that patients prefer and value most (Walsh et al., 2012; ACC, 2015). In cardiovascular imaging, adapting imaging practices to patients' preferences has been associated with improved imaging diagnostic and prognostic performance (DePuey et al., 2012). Specific patient-centered protocols have continuously been developed with an aim to improve patient satisfaction in cardiac testing procedures (Breen et al., 2009; Salimi et al., 2017). With the growing number of alternative imaging techniques and the comparative effectiveness, guidance on the benefits, costs, and place of these different techniques in the diagnostic pathway is needed. While most of the time and effort have been spent on technological breakthroughs, little attention has been devoted to patients' satisfaction (van Waardhuizen et al., 2016). In this context, the purpose of this to answer the following research question: What characteristics of advanced non-invasive cardiovascular imaging tests are most important for patients who are most likely to undergo imaging to characterize coronary stenosis, and for physicians who are most likely to order a cardiac imaging test for their patient?

3. METHODOLOGY

3.1. STUDY DESIGN

This study utilized a cross-sectional discrete choice experiment (DCE) questionnaire (Watson et al., 2016). The focus of this research was to assess patients' and physicians' preferences for distinctive features of cardiac imaging modalities used for diagnosing coronary artery disease. DCE designs have previously demonstrated to be effective at determining the relative preference of and importance attributed to health-related procedures and interventions in patients and physicians (Harrison et al., 2017). With this design, the current study may guide imaging technology development and clinical decision-making (Lancsar et al., 2013; Clark et al., 2014; Mandeville et al., 2014).

Mangham et al., (2009) described a DCE as "a quantitative technique for eliciting individual preference [that allows] researchers to uncover how individuals value selected attributes of a program, product or service by asking them to state their choice over different hypothetical alternatives" (p. 113). A DCE is known to be a straightforward task that closely emulates a real-world decision. The DCE questionnaire requires participants to state their choice over sets of hypothetical alternatives, where each alternative is described by several characteristics, known as attributes, and responses are used to infer the value, or utility, placed on each attribute. In health literature, the health services attributes of scenarios may include factor such as price, efficacy, dosage, formulation and side effects (de Bekker-Grob et al., 2012). The extent to which an individual places utility to a health service is expected to vary as a function of the levels of the attributes presented. DCEs can, therefore, allow measuring the significance of the attributes that describe the service as well as the extent to which participants are willing to tradeoff between service attributes (Drummond et al., 2005).

This study carefully followed the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) Guidelines for DCEs and conjoint analysis applications in health (Bridges et al., 2011; Johnson et al., 2013; Hauber et al., 2016). These Guidelines provide

consensus-based recommendations for the different phases of a stated-preference study. The guidelines are displayed in Table 1 (Bridges et al., 2011).

Table 1

Checklist for Conjoint Analysis Applications in Healthcare.

1. Was a well-defined research question stated and is conjoint analysis an appropriate method for answering it?

1.1 Were a well-defined research question and a testable hypothesis articulated?

1.2 Was the study perspective described, and was the study placed in a particular decision-making or policy context?

1.3 What is the rationale for using conjoint analysis to answer the research question?

2. Was the choice of attributes and levels supported by evidence?

2.1 Was attribute identification supported by evidence (literature reviews, focus groups, or other scientific methods)?

2.2 Was attribute selection justified and consistent with theory?

2.3 Was level selection for each attribute justified by the evidence and consistent with the study perspective and hypothesis?

3. Was the construction of tasks appropriate?

3.1 Was the number of attributes in each conjoint task justified (that is, full or partial profile)?

3.2 Was the number of profiles in each conjoint task justified?

3.3 Was (should) an opt-out or a status-quo alternative (be) included?

4. Was the choice of experimental design justified and evaluated?

4.1 Was the choice of experimental design justified? Were alternative experimental designs considered?

4.2 Were the properties of the experimental design evaluated?

4.3 Was the number of conjoint tasks included in the data-collection instrument appropriate?

5. Were preferences elicited appropriately, given the research question?

5.1 Was there sufficient motivation and explanation of conjoint tasks?

5.2 Was an appropriate elicitation format (that is, rating, ranking, or choice) used? Did (should) the elicitation format allow for indifference?

5.3 In addition to preference elicitation, did the conjoint tasks include other qualifying questions (for example, strength of preference, confidence in response, and other methods)?

6. Was the data collection instrument designed appropriately?

6.1 Was appropriate respondent information collected (such as sociodemographic, attitudinal, health history or status, and treatment experience)?

6.2 Were the attributes and levels defined, and was any contextual information provided?

6.3 Was the level of burden of the data-collection instrument appropriate? Were respondents encouraged and motivated?

7. Was the data-collection plan appropriate?

7.1 Was the sampling strategy justified (for example, sample size, stratification, and recruitment)?

7.2 Was the mode of administration justified and appropriate (for example, face-to-face, pen-and-paper, web-based)?

7.3 Were ethical considerations addressed (for example, recruitment, information and/or consent, compensation)?

8. Were statistical analyses and model estimations appropriate?

8.1 Were respondent characteristics examined and tested?

8.2 Was the quality of the responses examined (for example, rationality, validity, reliability)?

8.3 Was model estimation conducted appropriately? Were issues of clustering and subgroups handled appropriately?

9. Were the results and conclusions valid?

9.1 Did study results reflect testable hypotheses and account for statistical uncertainty?

9.2 Were study conclusions supported by the evidence and compared with existing findings in the literature?
9.3 Were study limitations and generalizability adequately discussed?

10. Was the study presentation clear, concise, and complete?
10.1 Was study importance and research context adequately motivated?
10.2 Were the study data-collection instrument and methods described?
10.3 Were the study implications clearly stated and understandable to a wide audience?

3.2. RATIONALE FOR DESIGN

As mentioned previously, the primary objective of this study was to inform healthcare professionals and policy-makers by contributing to the understanding of patient and physician preferences in relation to the choice of advanced non-invasive cardiovascular tests and imaging modalities used for diagnosing coronary heart disease. For ethical reasons, requiring subjects to experience multiple imaging procedures to ascertain their preference may not be feasible. A DCE design can allow gathering information about participants' preference of different imaging tests without requiring them to personally experience these tests (Pfarr et al., 2014). Thus, with a DCE, researchers acquire stated preference data (what people say they would do), rather than revealed preference data (what people actually do) (Hicks, 2002).

In eliciting preferences related to health outcomes and healthcare services, DCEs are widely used and accepted to identify and evaluate the relative importance of several aspects of decision-making. As opposed to many other stated-preference methods, DCEs enable an experimental and systematic investigation of the importance of particular characteristics of the available options as well as the relative importance of the characteristics (Luyten et al., 2015; Jonston et al., 2017). In addition, DCE studies have been considered excellent at comparing values and preferences for health services between patients and health professionals (Harrison et al., 2017). In a DCE study, researchers use an experimental design to map the study features of interest (attributes) and likely ranks (levels) into sets of alternatives to which participants indicate their choices. The levels of the attributes are varied systematically across alternatives. The relative importance of the attributes and the trade-offs individuals make when choosing one alternative over another are usually estimated through regression analysis of the choice data (Chua et al., 2016).

3.3. DEVELOPMENT OF THE DCE

When designing a DCE, attributes and levels must be determined and the type of models to be used need to be chosen (Johnson et al., 2013).

As suggested by the ISPOR Guidelines for DCEs and conjoint analysis applications in health (Bridges et al., 2011; Johnson et al., 2013), the attributes and levels of this DCE have to be chosen based on scientific literature (i.e. comparing different cardiovascular imaging modalities used for the diagnosis of coronary heart disease), and by conducting a preliminary qualitative investigation that includes observatory fieldwork, and consultations with key informants (i.e. patients and physicians) (Pinto et al., 2017).

3.3.1. Preliminary Qualitative Interviews

Undertaking preliminary qualitative research that incorporates a thorough literature review to determine the range of attributes and levels to be included in the final DCE design has been recommended to adequately guide and inform of DCE studies, and has been shown to add deeper understanding to DCE results (Louviere et al., 2000; Bridges et al., 2011; Coast et al., 2011; Pinto et al., 2017). This approach has also been shown to refine DCE attributes and levels as well as to ensure comprehensible survey terminology (Vass et al., 2017). Thus, prior to beginning the DCE, a preliminary qualitative investigation was conducted to verify the relevance of extracted attributes and levels from literature.

3.3.1.1. Key Informants

Eligible key informants for the preliminary qualitative interviews followed the same eligibility criteria as participants eligible to complete the DCE questionnaire (see section 3.6). Key

informants were recruited through a purposeful sampling strategy, which has been suggested to be particularly useful in qualitative descriptive studies to ensure maximum variation (Creswell & Poth, 2017). Prior research using qualitative interviews to guide DCEs showed that 10 to 15 participants would be sufficient to reach data saturation (Coast et al., 2004).

3.3.1.2. Qualitative Methodology

Semi-structured interviews were conducted with four healthcare professionals and thirteen cardiac patients to determine attribute levels, assess the clarity of wording for attributes and levels, and assess for comprehensibility of the questionnaire. Interviews were based on an informal interview guide that included discussion topics such as (1) their overall expectations and experiences with cardiac imaging modalities, (2) any knowledge about available cardiac imaging modalities, and (3) the factors that may guide their preference or decision-making in relation to cardiac imaging modalities. These interviews have been conducted in-person by Thomas Bertrand. Interviewees were also asked to refine language choice to ensure clarity, to discuss the proposed range of meaningful attribute levels, and indicate their most and least important test attributes. All key information from interviews was recorded, and an inductive constant comparative analysis method has been conducted. This analysis method was especially useful in reviewing interview information to verify and develop extracted attributes and levels. Information gathered reflected patterns of explicit content, thus reducing the chances for implicit bias, and the interview content provided more systematic and transparent information (Joffe & Yardley, 2004). Evident grammatical errors in the documents presented were immediately corrected. This qualitative investigation allowed the identification of a comprehensive range of patient and physician healthcare-related characteristics that influence their preference for features of cardiovascular imaging modalities (Vass et al., 2017).

3.4. ATTRIBUTES AND LEVELS

Following a preliminary literature review, six attributes applicable to cardiac imaging tests were drawn (patient out-of-pocket cost, risks and side effects, type of procedures, diagnostic accuracy, type of scanner and test duration). Table 1 shows a description of attributes and levels drawn from the literature review. The selected attributes and levels have been used to describe different cardiovascular imaging modalities and tests used to diagnose coronary heart disease and were revised according to the qualitative interviews and assessed for face validity. As per recent literature, these six attributes offer a comprehensive description of the core distinctions between existing cardiovascular imaging modalities and tests (Tilkemeier et al., 2016; Ladapo et al., 2016; Doukky et al., 2017). Following the preliminary interviews, no major changes were made to the attributes, but the certain levels were added and others were modified. Specifically, the description of the types of procedure, types of scanner, and risks and side effect was adapted to the knowledge level of a non-scientific audience. The cost attribute originally had three levels ($500, $750, and $1000), but qualitative interviews with cardiologists and further review of literature guided the addition of a fourth level with a change in price scale. As recommended when aiming at assessing concordance between patient and physician preferences, both groups were provided with the same attributes and levels (Harrison et al., 2017).

Table 2 presents a description of the reviewed and final attributes and levels. Table 3 displays imaging tests and modalities of interest and compares them according to their characteristics and the associated expected preferences.

Table 2

DCE Attributes and Levels

Test Attributes	**Levels**
Type of procedure	Exercising
	Pharmacological agents
	Breathing maneuvers
Duration	30 minutes
	60 minutes
Patient out-of-pocket	$500
cost	$1000
	$1500

	$2000
Type of scanner	No scanner
	Partial body scanner
	Complete body scanner
Risks and side effects	Possible tingling in the fingers, dizziness and dry mouth.
	Possible chest pain, irregular heartbeat, flushing, and breathing difficulties and a 0.1% (1 in 1,000) chance of serious complications such as heart attack.
	Exposure to radiation and a 0.1% (1 in 1,000) increase in cancer risk.
Diagnostic accuracy	90%
	80%
	70%

3.4.1. Patient Out-of-Pocket Cost

Cost attributes have been widely used in healthcare-related DCEs (Kragt & Bennett, 2010; Johnson et al., 2011; Laba et al., 2015; Walker et al., 2017). Although in Canada Medicare covers most medical exams, the aim of using this attribute was to see how price estimates could influence participants' decision-making regarding their choice of imaging tests. The cost attribute was therefore described as patient out-of-pocket cost, and all participants were instructed to answer as though patients had to pay for their imaging test, similar to uninsured services from a private clinic. An extensive review of available literature was performed to create accurate and realistically representative levels of the cost attribute. However, data related to the cost of imaging procedure varies across countries, provinces and states, health institutions, and published reports. For example, after contacting government representatives in the province of Quebec, where this study took place, we were told that the actual cost of a radiological examination includes: professional fees for the interpretation of the exam, the technical component for performing the exam (technologist remuneration, clerical staff) and the cost of the apparatus (maintenance and depreciation). To obtain the actual cost of a radiological examination, the government mentioned it is under provincial jurisdiction and suggested contacting the hospitals that serve such services. The RAMQ is responsible for the reimbursement of professional acts and not the reimbursement of the technical component and the cost of maintaining equipment in hospitals, which varies across institutions. If we wanted more precise data, it would have been considered as a personalized

request, which requires realization costs. For this type of request, the fees are $100 and the timeframes to receive the information are usually within 3 to 6 months, as indicated online: http://www.ramq.gouv.qc.ca/fr/donnees-et-statistiques/citoyens/Pages/tableaux-donnees-statistiques.aspx. Because authors wanted the cost attribute to be more generable to other provinces and countries, this personalized request was not necessary.

Instead, a thorough review of available and published data was performed. A systematic review of 2010 Canadian public records portrayed details results for costs associated with cardiovascular imaging procedure (THETA, 2010). When adjusted with more recent professional and technical fees for cardiac radiology services, this review could provide useful information (Martinuk & Meyer, 2013). Cost-effectiveness studies could also report relevant information on comparative costs (Min et al., 2010; Thom et al., 2014; Pletscher et al., 2016; Bertoldi et al., 2017). Other public and governmental reports on schedules of medical benefits reimbursement schedules are made public by, for example, the Centers for Medicare & Medical Services (CMS), the Ontario Health Insurance Program (OHIP), the Régie de l'assurance maladie du Québec (RAMQ), and the Comité de coordination des ententes interprovinciales en assurance santé (CCEIAS). These sources could be used to derive different medical imaging services' costs. Medical societies, such as the Society of Cardiovascular Computed Tomography (SCCT) also published reimbursement charts: http://scct.org/?page=2017ReimbursementCha (Martinuk, 2013). Some private services also made their imaging tests' price list available online.

Considering all these sources, there was general agreement that non-invasive advanced cardiovascular imaging tests cost between $500 and $2000 (Consumer Reports, 2015). Based on this agreement, four levels were created ($500, $1000, $1500, and $2000). This price interval was linear and followed the equation 500*n, with n=1 through 4. Levels were described as: a test price of about $500 is a cheaper test, a test price of about $1000 is neither cheap nor expensive, a test price of about $1500 is neither cheap nor expensive, and a test price of about $2000 is an expensive test. Although using price ranges could have more flexibly representing the imaging techniques' cost differences, DCE guidelines stated that the use of ranges to define attributes should be avoided because this requires the participant to subjectively interpret the levels, and a subsequent ambiguity may affect the results (Bridges et al., 2011). In a hypothetical scenario where patients are expected

to spend money for their cardiovascular imaging test, less costly alternatives were expected to be preferred in both patients and physicians.

3.4.2. Diagnostic Accuracy

Attributes related to diagnostic or treatment accuracy have also been repeatedly used in DCE literature (Ghanouni et al., 2014; Beulen et al., 2015; Hill et al., 2016; Taylor et al., 2017; Hill et al., 2017). In two DCE studies comparing health users' and professionals' preferences, Hill et al., (2016-2017) reported that treatment accuracy was significantly more important to health professionals. Literature on the different cardiovascular imaging tests' accuracy for diagnosing CAD is extensive, and often provides fluctuating results (Gianrossi et al. 1989; Mancini et al., 2014; Alexanderson-Rosas et al., 2015; Budoff et al., 2016; Skelly et al., 2016; Fordyce & Douglas, 2016; Danad et al., 2017; Mordi et al., 2017). Yet, most studies that combined measures of specificity and sensitivity placed tests' diagnostic accuracy varying from approximately 70% to 90% (Siontis et al., 2018). For example, diagnostic accuracy measures were derived from a review article comparing core advanced cardiovascular imaging methods for diagnosis CAD when compared to the invasive gold standard ICA showed that PET and CMR exams were associated with about 90% accuracy, echography and CT exams were associated with about 80% accuracy, and SPECT was associated about 70% accuracy (Balfour et al., 2017).

Following these findings, three levels of the diagnostic accuracy attribute were created: 70%, 80%, and 90%. The level description table showed that more accurate tests have higher chances of providing correct results (about 90%), some tests have moderate chances of providing correct results (about 80%), and less accurate tests have lower chances of providing correct results (about 70%). When reports of diagnostic accuracy were not available, measures of tests' sensitivity and specificity were combined. Of note, there was no published data on the diagnostic accuracy of the b-CMR technique, but preliminary results from our group showed that the accuracy of the technique may be comparable to that of the pharmacological agent method used during MRI cardiac stress tests and to that of ICA (Fischer et al., 2016; Fischer et al., 2018). Nonetheless, because this technique is relatively new and more research needs to be performed, b-CMR was

associated with an 80% diagnostic accuracy in the current study. Although tests with greater accuracy are anticipated to be preferred in both patients and physicians, we anticipate that this preference will be greater in the physician group, as found in Hill et al., (2016-2017).

3.4.3. Type of Procedure

The type of medical intervention or procedure performed in clinical imaging protocols is an important factor differentiating cardiovascular imaging tests (Safavi et al., 2014; Roşca & Popescu, 2016; Danad et al., 2017). As mentioned previously, a stress test provides images of how the myocardium contracts and distributes blood throughout, both at rest and at stress, which usually directly proceeds a medical intervention such as exercise, breathing maneuvers, or pharmacological agents. In the current study, these three types of procedure were studies: exercise, breathing maneuvers, and pharmacological agents. Each procedure has its specific advantages and disadvantages, which were explained in detail in section 2.1. The description of levels provided to patients went as followed: breathing maneuvers is a technique in which patients are asked to perform fast breathing for 60 seconds, and then to hold their breath for 30 to 45 seconds while staying still, exercising: is a technique in which patients are asked to walk or run on a treadmill that gradually increases in speed and inclination until criteria for test termination are met, and pharmacological agents: is a technique in which patients are injected, through a vein of the arm, a drug that has a direct and transient effect on the body (such as a change in heart rate and blood pressure) while they are asked to stay still.

To our knowledge, users' preferences for these three types of procedure have not been studied and compared simultaneously in a study. Thus, authors were not able to estimate which procedure would be preferred in a DCE. Nevertheless, in patients, exercise has been reported to be preferred over pharmacological injections in echography (Gonzalez & Beller, 2017), and breathing maneuvers have been preferred over pharmacological agents in CMR (Fischer et al. 2014). However, the choice of procedure chosen typically depends on the patients' ability to exercise and their propensity to receive pharmacological agents, physicians' expertise, and the

availability of required medical equipment (Grobner & Prischl, 2007; Fihn et al., 2012; Nishimura et al., 2014; Mancini et al., 2014).

3.4.4. Test Duration

Time-related attributes have been used to characterize medical services and interventions in health literature (Boormans et al., 2010; Clark et al., 2014). For example, in a DCE on colorectal cancer screening programs, test duration was identified as an important attribute (van Dam et al., 2010). To our knowledge, this attribute has not been studied as central characteristics that are likely to influence decision-making in non-invasive cardiovascular imaging tests. Patient time in the scanner is a feature that varies between tests and may differ between imaging modalities. Efforts to reduce medical interventions' length are continuously made, and shorter tests are often desired by health professionals and patients (Ho et al., 2015; Levine et al., 2016; Boyajian, 2016). Thus, constant progresses to shorten image acquisition time (and waitlist alongside) and considering the growing demand for timely healthcare services in non-invasive cardiovascular imaging procedures have suggested this feature was an important attribute to include in the DCE (Van der Pol & Cairns, 2001; Henzlova et al., 2006; Husain, 2007; Fihn et al., 2014; Ishii et al., 2016; Wolk et al., 2017; Polanec et al., 2018).

Many variables can affect a cardiovascular imaging test's duration. The scanning time depends on the imaging modality used, the type of procedure performed, and the skills and experience of physicians and medical staff. Typically, cardiovascular imaging tests for the diagnosis of CAD take between thirty minutes and one hour to be performed. As a result, two levels were created: 30 minutes and 60 minutes. Patients and physicians were anticipated to favor faster exams. Levels were described as: tests that are completed within about 30 minutes are considered shorter, and tests that are completed within about 60 minutes are considered longer. Of note, the test duration attribute was considered as the least important from many key informants during the qualitative interviews. However, because some key informants reported it was a very important factor influencing their choice of test, we included it in the DCE.

3.4.5. Type of Scanner

The type of scanner is a modality-dependent feature. For example, MRIs and CT scanners are differing in size and functions. In medical ultrasounds, patients are not required to enter a scanner to be tested for CAD. These intrinsic modality-dependent differences were therefore considered as important and fundamentally different test-specific attributes. In a DCE on scanning modalities to diagnose focal liver lesions, the type of scanner used was studied and has been shown to influence patient preferences for diagnostic imaging tests (Whitty et al., 2015).

In the current study, the scanner type attribute was composed of three levels: Complete body scanner, partial body scanner, and no scanner. These levels were described as: no scanner: patients lie down on a bed, and a gel and a small device are applied on patients' chest, partial body scanner: patients lie down within a scanner which surrounds only a part of their body, and complete body scanner: patients lie down within a scanner which surrounds most of their body. Due to facilitated access and communication involved in examinations performed outside a scanner, it was expected that both physicians and patients would place a higher value on the "no scanner" choice.

3.4.6. Common Risks and Side Effects

The influence of possible risks and side effects on decision-making and users' preference has repeatedly been investigated in DCE studies (Clark et al., 2014). In most studies assessing treatment risks or side effects as an attribute, results revealed it as being an important factor for patients (Hauber et al., 2013; Harrison et al., 2014; Harrison et al., 2015). As expected, patients tend to prefer treatment options without side effects but may be willing to trade-off side effects for less costly treatments, for example (Dong et al., 2016). In a DCE on acute coronary syndrome patients, participants revealed preferring to reduce mortality risk above all else (Mühlbacher et al., 2015). This attribute has also been suggested to be important for treating physicians (Rodvanna,

2014). Nevertheless, risks and side effects, or treatment safety, have been ranked as types of process attributes, which are generally more important to patients (Harrison et al., 2017).

Different procedures and modalities in cardiovascular imaging for diagnosing CAD have been associated with a range of risks and side effects. For example, breathing maneuvers during CMR have been associated with tingling in the fingers, dizziness and dry mouth (Fischer et al., 2014; Fischer et al., 2018). Physical exercise and the use of pharmacological stress agents in CMR, ultrasound and nuclear medicine have been associated with chest pain, irregular heartbeat, flushing, breathing difficulties, and rare (0.1%) chance of serious complications such as death or heart attack (PubMed Health, 2014; Dilsizian et al., 2015; Rai et al., 2017). A study comparing exercise and pharmacological agent techniques in cardiovascular ultrasound also reported that the two procedures have similar side effects (Craft et al., 2016). Furthermore, exposure to ionizing radiation has been described as a common risk associated with nuclear medicine and CT modalities (Lehnert & Bree, 2010; Huda et al. 2011, Blomster et al., 2016; Schmermund et al., 2017). Although it remains difficult to precisely measure the risks associated with exposure to imaging modalities-related ionizing radiation, reports of a 0.1% increase in the lifetime risks of developing cancer were considered likely to influence patient and physician decision-making, even if the physical effects may not be acutely perceivable (Fazel et al., 2009; Chen et al., 2010; Einstein, 2012; Picano et al., 2014; Richardson et al., 2015). In this context, three levels of the risks and side effects attribute were created: 1) Patients may experience tingling in the fingers, dizziness and dry mouth. These side effects usually disappear within seconds, 2) Patients may experience chest pain, irregular heartbeat, flushing, and breathing difficulties. These side effects usually disappear within seconds. There is a 0.1% (1 in 1,000) chance of serious complications such as heart attack, and 3) Patients are exposed to radiation. Radiation has been associated with a 0.1% (1 in 1,000) increase chance of risks of cancer. Less serious side effects (tingling in the fingers, dizziness and dry mouth) were expected to be preferred by both patients and physicians, but especially by patients.

3.4.7. Other Attributes

Previous reports have also raised the impact of modality and expertise availability on clinical decision-making (Ginde et al., 2008; Fihn et al. 2012; Douglas et al., 2016). However, a DCE that compared waiting time for liver scanning modalities showed that, although statistically significant, this attribute was particularly variable and influenced by participants' personal characteristics (Whitty et al., 2015). Despite its center-dependent nature, the availability of imaging modalities was considered generally comparable in Canada, making the fragmentation of this DCE attribute in distinctive levels problematic (The Canadian Medical Imaging Inventory, 2016). The availability and wait time attribute also was not considered as important on its own in the preliminary qualitative interviews. Thus, this attribute was not added to the DCE design.

Table 3

Feature Comparison of Cardiovascular Imaging Modalities with Expected Preferences

Technique Features	**Magnetic Resonance Imaging**		**Nuclear Medicine**		**Echography**		**CT**
	With pharmacological agent	**With breathing maneuvers**	**SPECT**	**PET**	**Exercise**	**With pharmacological agent**	**-**
Cost	1500$	1000$	1000$	2000$	500$	500$	500$
Type of procedure	Pharmacological agent	Breathing maneuvers	Pharmacological agent	Pharmacological agent	Exercise	Pharmacological agent	Pharmacological agent
Total time in the scanner	About 60 minutes	About 30 minutes	About 60 minutes	About 60 minutes	About 30 minutes	About 30 minutes	About 30 minutes
Type of scanner	Complete body scanner	Complete body scanner	Partial body scanner	Partial body scanner	No scanner	No scanner	Partial body scanner
Common risks and side effects	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a (0.1%) chance of serious complications	Tingling in the fingers, dizziness and dry mouth	Chest pain, irregular heartbeat, dizziness, flushing, breathing difficulties, and a (0.1%) chance of serious complications & Exposure to radiation	Chest pain, irregular heartbeat, dizziness, flushing, breathing difficulties, and a (0.1%) chance of serious complications & Exposure to radiation	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a (0.1%) chance of serious complications	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a (0.1%) chance of serious complications	Exposure to radiation and a 0.1% increase chance in risks of cancer.
Accuracy of the test	Moderate (about 80% accuracy)	High (about 90% accuracy)	Low (about 70% accuracy)	High (about 90% accuracy)	Moderate (about 80% accuracy)	Moderate (about 80% accuracy)	Moderate (about 80% accuracy)

Color Legend			
Most preferable option	Nor most, nor least preferable option	Least preferable option	Preference unknown

3.5. EXPERIMENTAL DESIGN

To optimize utility measurements in healthcare interventions, the choice of valuation technique must be carefully chosen according to the type of preference elicitation technique and the number of choice sets each participant faces (Bansback et al., 2014). The standard gamble and the time tradeoff methods are used to measure utilities have been subject to criticism and to involve many types of biases (Patrick et al., 1994; Van Osch et al., 2004; Craig & Ramachandran, 2006). A DCE is an alternative technique that makes use of ordinal preferences using ranking that is based on random utility theory. This theory posits that people generally choose what they prefer, but it also assumes that their decision includes a portion of error due to random factors. Participants' error may include questions-related fatigue, inattention, confusion or misunderstanding, and may be minimized by improving on the experimental designs' response efficiency (Johnson et al., 2013). By accounting for these errors, DCEs' preference elicitation technique is more robust and can accommodate for mistakes made by participants in the valuation exercise (Ryan et al., 2006). In addition, because stated-preference methods, as opposed to revealed-preference methods, allow controlling the stimuli that generate the data, the choice of experimental design must satisfy a very high standard for statistical efficiency. Conducting a DCE involves a careful selection of experimental design to obtain unbiased parameter estimates from the data for every parameter in the model. To allow independent variation between attributes, the design should depend on the attribute levels within and across choice questions and include sufficient numbers of attribute-level combinations (Johnson et al., 2013).

Thus, the current DCE used a choice-based conjoint (CBC) design (https://www.sawtoothsoftware.com/products/conjoint-choice-analysis/cbc). A free academic subscription license of the Sawtooth Software (3210 N Canyon Road # 202, Provo UT, 84604-6508, United States of America) program and full access to all necessary software products were granted for this study. Sawtooth Software is users' friendly and does not require programming skills. The subscription license included the design software, as well as a complete implementation of survey-instrument construction, administration, and analysis (Orme, 2009). The CBC module samples from a subset of the full-choice design for each participant while keeping appropriate level

balance, minimal overlap and near-orthogonality within each participant's response profile, with limited exploration of pre-specified interactions (Sawtooth Software, 1998). Unlike other designs, this allows to prevent systematic correlations among interactions intrinsic to fixed designs, so that main effects and higher-order interactions can, therefore, be more robustly estimated (Johnson et al., 2013). In addition, using a unique randomized design for each participant typically reduces context-specific errors, and allows to draw unique profiles with replacement from a subset of the full-choice design. As all combinations of levels are plausible, no deviation from the experimental design was required (Kifmann and Wagner, 2014). Incorporating all possible combinations, is, in some circumstances, valuable because it enables all interaction effects to be investigated (Greiner & Ballweg, 2013). Nonetheless, in the CBC analysis module, estimates of interaction effects are unbiased, but the efficiency of the estimate depends on sample size (Johnson et al., 2013). We considered using the Adaptive Choice-Based Conjoint (ACBC) due to reports indicating evidence that ACBC may require lesser sample size, and obtain more precise estimates than CBC (Chapman, 2009). However, there were no pen-and-pencil questionnaires available with ACBC, which was expected to be preferred and increase feasibility in older participants, and further justified the decision to use the CBC design.

Following recommendations from the CBC module given the study design and expected sample size, seven versions of a Traditional Full-Profile CBC design were created, each containing 12 random pairwise choice scenarios (tasks) and two concepts per tasks. As a result, a total of 84 choice tasks were created. In other health applications of DCEs, most studies included between 9 and 16 choices scenarios, which is generally not considered too cognitively demanding for participants (Bech et al., 2011; Clark et al., 2014). In each questionnaire, one choice scenario was duplicated as a fixed task, and responses to the duplicated choice were not included in the preference model (Whitty, 2015). This resulted in a total of 13 choice sets in all seven questionnaire versions (Appendix I). Out-of-pocket costs of the test and diagnostic accuracy were coded as numerical variables, while all other attributes were coded as discrete variables. Some DCEs include an opt-out (or status-quo) choice as a third alternative to offer the possibility to participants who prefer none of presented alternatives to not select any. Although considered, we decided not to include an opt-out option because it was considered more clinically representative and we, therefore, inferred in the provided hypothetical scenario presented that a test had to be ordered. In

addition, we did not want to limit our ability to estimate the underlying preference by censoring our data (Bridges et al., 2011).

As mentioned previously, the choice of attributes and levels included in the experimental design was verified with the preliminary qualitative investigation. Using a two-alternative design including 6 attributes (one attribute of four levels, four attributes of three levels, and one attribute of two levels) yielded 648 ($4^1 * 3^4 * 2^1$) possible profiles and produced 209 628 [($4^1 * 3^4 * 2^1$) (($4^1 * 3^4 * 2^1$) – 1)/2] possible combinations of two-alternative choice questions with balanced overlap. Although statistical efficiency of a DCE design are commonly calculated using d-efficiency, this metric is not always the best predictor of how efficient the experimental design will be in practice to precisely estimate utilities (Maddala et al., 2003; Arbiol et al., 2015). The default design method in Sawtooth Software is rather called Balanced Overlap and loses some d-efficiency for the benefit of achieving a modest degree of level repeats within each task (overlap). Level overlap makes it more difficult for participants to engage in non-compensatory decision-making and always chose an alternative by only considering one attribute. This approach leads to an efficient estimation of all potential first-order interaction effects so that the design better support all main effects and first-order interaction effects (Orme, 2009). In addition, as all combinations of levels were conceptually plausible in the current DCE, no deviation from the experimental design was required (Kifmann and Wagner, 2014). Incorporating all possible combinations has been considered, in some circumstances, valuable because it enables all interaction effects to be investigated (Greiner & Ballweg, 2013).

3.5.1. Methods for minimizing bias

To reduce the hypothetical bias associated with stated-preference studies, a detailed description of all attributes and levels was provided prior to, and made available during, the experiment, which encouraged participants to think carefully on how the attributes and levels can influence their medical workup. This could help reducing error due to random factors (Özdemir et al, 2009).

Discrete choice analysis requires that people make trade-offs between levels of specified attributes and it is appropriate to test that trading takes place. In some cases, the participant is unwilling to accept reductions in one attribute in return for improvements in others, exhibiting a so-called lexicographic preference with respect to the attribute preferred. In this case, the participant tends to make a decision based on one attribute only, without trading between the other ones (Bryan et al., 1998). As it was expected that some participants would have such a fixed lexicographic preference for some attributes, this study was designed, as mentioned previously, to evaluate participants' preferences including or not lexicographic participants.

3.6. STUDY POPULATION

3.6.1. Participants and Sample Size

A convenience sample of cardiac patients admitted to the Royal Victoria cardiology clinic, and physicians, including family physicians and cardiologists, associated with the McGill University Health Center were asked to complete the DCE questionnaire. The patient group included cardiac patients who were scheduled to undergo cardiovascular imaging to characterize coronary stenosis, and the physician group included types of physicians who were most likely to order a cardiovascular imaging test for their patients. Sample size calculation in DCE studies in healthcare remains ambiguous. A review of healthcare-related DCEs focusing on sample size showed that about a third of DCEs has a sample size smaller than 100 and that most DCE studies (41%) usually enroll between 100 and 300 participants (de Bekker-Grob et al., 2015). As mentioned previously, seven questionnaire versions were recommended and created for this DCE. Thus, following the rule of thumb proposed by Pearman et al. (2000), and with reports that 20 participants per questionnaire version could provide precise parameter estimates and reliable models (Hall et al., 2004; Lancsar & Louviere, 2008), we aimed at recruiting a minimum of 140 participants to reach a sufficiently large sample.

3.6.2. Eligibility Criteria

3.6.2.1. Inclusion criteria (patient group)

Subjects over 18 years of age admitted at the Cardiology Clinic of the Royal Victoria Hospital for a heart-related condition and who were thus likely to undergo a cardiovascular imaging test for diagnosing coronary artery disease.

3.6.2.2. Inclusion criteria (physician group)

Physicians (family physicians or cardiologists) who were likely to refer their patient for a cardiovascular imaging test for diagnosing coronary artery disease. No other specific selection criteria were used.

3.6.2.3. Exclusion criteria

1) The subject was unwilling or unable to give implied and informed consent for the participation in the study. 2) The subject could not read or communicate in English or French. 3) The subject had a severe learning disability or mental disorder (i.e. acute psychosis, autistic disorder, advanced Alzheimer's disease) that could have affected their ability to respond to the questionnaire (Johnson et al., 2013).

3.7. PROCEDURES

3.7.1. Timeline & Ethics Review

The research proposal of this study was submitted to the McGill University Health Centre Research Ethics Board on November 14th, 2017, and was reviewed by the Cells, Tissues, Genetics & Qualitative research panel (CTGQ). The research proposal received a final approval on December 19th, 2017. The first participant was recruited on January 16th, 2018, and the last completed questionnaire was received on March 5th, 2018. Data analyses and thesis redaction were concurrently performed until the end of May 2018,

3.7.2. Recruitment and Consent

The study took place at the Research Institute of the McGill University Health Center (MUHC) in Montreal, Canada. Montreal is the metropole of the province of Quebec, where citizens generally speak either French, English, or both. Patients were recruited in person in the waiting room of the MUHC's Royal Victoria cardiology clinic while waiting for their medical appointment. Patients completed the pen-and-paper questionnaires and a researcher was available to speak the instructions and answer questions. Family physicians were either contacted using a standardized research participation invitation by email from a MUHC senior administrator, or via a link posted on the North American Primary Care Research Group (NAPCRG) announcement board for physician members. Cardiologists were contacted through their MUHC email by the study researchers using a standardized research participation invitation by email (Appendix C).

An implied consent was used for this study considering the minimal risks involved with participation and to ensure complete anonymity (Appendices A, B, D, and E). All participants were informed that their participation in the study was voluntary, that they could withdraw from the study at any time, without providing a reason and that their refusal/withdrawal of consent would not affect their subsequent medical assistance and treatment. After submitting their questionnaire, participants were thanked for their participation and no financial compensation was given.

Specific ethical considerations were also given in the preliminary qualitative phase of this study. Key informants' participation in the preliminary qualitative research was voluntary, and endeavor to ensure that decisions about participation in research from an informed position have

been made. Specific personal information from the qualitative interviews was not be reported, and key informants' data was treated with confidentiality and anonymity. According to qualitative research ethical codes of conduct, the interviewer ensured that informants were protected from undue intrusion, distress, indignity, physical discomfort, personal embarrassment, or psychological or other harm (Fritz, 2008). Those who refused to answer questions were free to do so at any time and without consequences. This preliminary qualitative interview was conducted with the aim to inform and confirm the face validity of the DCE attributes and levels, and thus interviewees were encouraged to provide their honest opinion without being judged. They were informed that there were no right or wrong answer and that the researcher would record their opinion in a non-judgmental manner. All interviews and methodological steps ensured that the preliminary qualitative interviews were conducted with trustworthiness and rigorousness, in line with the seven criteria for good qualitative research reported by Cohen and Crabtree (2008).

3.7.3. Questionnaire

A questionnaire was constructed for the DCE using Sawtooth Software' CBC design. The online questionnaire was hosted by the Sawtooth Software's Hosting Services - Lighthouse Studio (https://www.sawtoothsoftware.com/products/online-surveys). From the online questionnaire, paper-and-pencil questionnaires with the same seven versions were created to be distributed to patients, with the expectation it would be easier for them, especially for older patients, to complete hard copies. Physicians completed the online version for feasibility purposes. The questionnaire was translated into French and available to all participants in both English and French. Prior to answering the choice experiment, participants were asked to read the implied consent form and, therefore, by continuing to the questionnaire, participants provided implied consent to participate in the study. Participants were then directed to *Part 1*, where they were asked to answer a few questions about themselves and their history with different cardiovascular imaging. The demographic questionnaire was concurrently used for ensuring eligibility (Appendices F and G**)**. The next page displayed a table of description to allow participants to familiarize themselves with the attributes and levels used in the DCE (Table 4). Participants were commanded with the following text: "The table below shows the characteristics of cardiac tests you will see in the

following questions. Please take the time to familiarize yourself with these characteristics before you continue".

Table 4

Description of Final Attributes

Cardiovascular imaging tests may vary in terms of cost, type of procedure, risks and side effects, duration, type of scanner, and accuracy.

Cost
The costs of cardiovascular imaging tests can vary.

- *A test price of about **$500** is a cheaper test.*
- *A test price of about **$1000** is neither cheap nor expensive.*
- *A test price of about **$1500** is neither cheap nor expensive.*
- *A test price of about **$2000** is an expensive test.*

Type of procedure
Different methods can be used to complete cardiovascular imaging tests.

- ***Breathing maneuvers** is a technique in which patients are asked to perform fast breathing for 60 seconds, and then to hold their breath for 30 to 45 seconds while staying still.*
- ***Exercising**: is a technique in which patients are asked to walk or run on a treadmill that gradually increases in speed and inclination until criteria for test termination are met.*
- ***Pharmacological agents**: is a technique in which patients are injected, through a vein of the arm, a drug that has a direct and transient effect on the body (such as a change in heart rate and blood pressure) while they are asked to stay still.*

Test duration
The duration of cardiovascular imaging exams can vary.

- *Tests that are completed within about **30 minutes** are considered shorter.*
- *Tests that are completed within about **60 minutes** are considered longer.*

Type of scanner
The type of cardiovascular imaging device or scanner can vary.

- ***No scanner**: Patients lie down on a bed, and a gel and a small device are applied on patients' chest.*
- ***Partial body scanner**: Patients lie down within a scanner which surrounds only a part of their body.*
- ***Complete body scanner**: Patients lie down within a scanner which surrounds most of their body.*

Common risks and side effects
Like in many radiological procedures, there are common risks and side effects associated with cardiovascular imaging tests. These risks and side effects can vary from test to test.

- *Patients may experience tingling in the fingers, dizziness and dry mouth. These side effects usually disappear within seconds.*
- *Patients may experience chest pain, irregular heartbeat, flushing, and breathing difficulties. These side effects usually disappear within seconds. There is a 0.1% (1 in 1,000) chance of serious complications such as heart attack.*
- *Patients are exposed to radiation. Radiation has been associated with a 0.1% (1 in 1,000) increase chance in risks of cancer.*

Accuracy of the test
The accuracy of cardiovascular imaging tests can vary. Less accurate tests may lead to erroneous results or require patients to perform further testing.

- *More accurate tests have higher chances of providing correct results (about **90%**).*
- *Some tests have moderate chances of providing correct results (about **80%**).*

- *Less accurate tests have lower chances of providing correct results (about **70%**).*

Then, in *Part 2*, participants were provided with detailed instructions prior to starting the DCE questions. The instructions given to participants were:

> In this section, you will be asked to select the cardiovascular test you prefer. Please read the instructions below carefully. Imagine you had to choose a cardiovascular imaging test (for the patient) in a private clinic. Different cardiovascular imaging techniques can be used to diagnose cardiovascular diseases. Each test differs with respect to certain characteristics. Some tests you are going to see may not currently exist, but we ask you to imagine they are available in reality. You are asked to choose the test you prefer. Assume all other characteristics of the tests are the same. Please answer all choices. Each question is different. There are no right or wrong answers. For each question, select which type of test you would prefer by considering each test characteristics (Test A or Test B).

For participants completing the DCE online, two "click-to-open" (in the same window) java scripts adapted from *w3schools.com* were created and readily available on each choice set pages to allow participants to review the DCE instructions and the table describing the attributes and levels. On each question page, participants were instructed: "Please select which type of test you prefer by considering each test characteristics. Select Test A or Test B". Figure 8 shows an example of a discrete choice task.

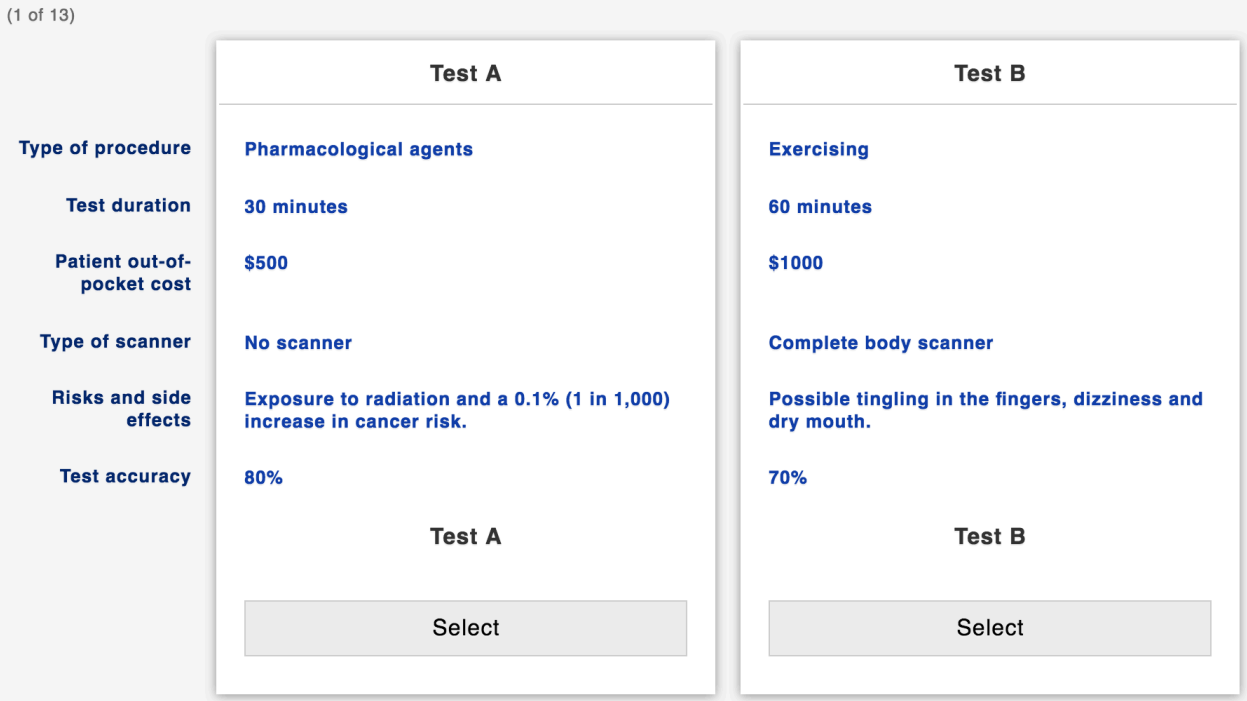

Figure 8. Example of a discrete choice task.

After completing the 13 choice tasks, participants were questioned about their perception regarding the difficulty of the questionnaire and asked on a 5-item difficulty scale (from very easy (1) to very hard (5): "How did you find this questionnaire?". This perceived difficulty question was used to estimate the validity of the responses. Participants were then thanked from their participation and the following messages appeared:

> Your responses have been recorded. Thank you for your participation in this study. If you have questions about the study you can communicate with the researcher: Thomas Bertrand ([phone number]), or with the investigator in charge of the study: Dr. Matthias G. Friedrich ([phone number]). For any questions concerning your rights as a person taking part in this study, or if you have comments or wish to file a complaint, you can communicate with the Hospital Complaint Commissioner/Ombudsman at the following number: ([phone number]).

Data was coded according to a predetermined detailed coding manual (Appendix H).

3.7.4. Data Analysis

3.7.4.1. DCE Hypotheses

H_0: No change in cardiovascular imaging attributes' level utility was statistically significant from zero.

H_1: At least one cardiovascular imaging attributes' level utility was statistically significant from zero.

3.7.4.2. Descriptive Statistics

Measures of central tendencies and frequency distributions were computed using the Statistical Package for the Social Science (SPSS) Statistics for Macintosh, Version 22.0 (IBM, 2013). Pearson's correlation coefficients were computed to assess the relationship between participants' reported difficulty and age, and education. Independent-samples t-tests were conducted to compare difficulty in French and English respondents, in males and females, in respondents who are familiar with at least one cardiovascular imaging test and those who are not familiar with any cardiovascular imaging tests, and in cardiologists and family physicians.

3.7.4.3. Main Statistical Model

In this DCE, variation in participants' preference for different attributes and levels was expected. For example, some participants could prefer exercising over pharmacological interventions or vice-versa. Thus, accounting for preference heterogeneity among participants, the Sawtooth Software's CBC/Hierarchical Bayes (HB) model has been repeatedly used (Wellman et al., 2008; Schreiber & Baier, 2015). According to Sawtooth Software, HB is the most frequently

used utility estimation approach among users, and its use for final models is strongly recommended, especially for developing utilities that can be used in software's market simulators (Orme, 2009). It was reported that Bayesian procedures provide a better approach than other analysis models to estimate preference weights for each individual in the sample, or when the sample size is small, and HB does not require the assumption of a common scale across participants (Regier et al., 2009; Hauber et al., 2016). This model also allows estimating both the mean and distribution for each attribute level, which has been shown to be valuable in this DCE design (Hole, 2007). HB is an extension of conditional logit that can be used to analyze the same DCE data. As explained by Hauber et al. (2016):

> HB models […] generate preference estimates for each individual in the sample and only supplement these individual-specific estimates with aggregate preference information to the degree that individual-specific preference information is insufficient (p. 407).

Unlike similar models, the HB model allows to model responses from each participant instead of all observations in the sample. Individual results could, therefore, be used to construct a (joint posterior) distribution of preference weights across participants by including the mean and standard deviation for the preference weight for each attribute level (Johnson et al., 2013; Hauber et al., 2016).

The HB estimation was applied to calculate relative importances of each test attribute on the choice for a particular cardiovascular imaging test (Orme, 2009), and confidence intervals (95% CI) were calculated to assess significance. A total of 20,000 sampling iterations, including 10,000 preliminary iterations and 10,000 draws used per participant, were computed to model estimation errors. The estimation was completed in less than 30 seconds. The difference in relative importances reflected the range in the attribute's utility values in percentage, and importances were directly related to the levels included in the DCE exercise (Orme, 2010).

3.7.4.3.1. Hierarchical Bayes formulas

The HB model followed the underlying conditional logit formulas, which were supplemented by an equation to characterize the variation of preferences across participants with assumptions that individual part-worths followed a multivariate normal distribution (Sawtooth Software, 2009; Hauber et al., 2016).

$$\beta_i \sim \text{Normal}(\alpha, D)$$

$$p_k = \exp(x_k' \beta_i) / \sum_j \exp(x_j' \beta_i)$$

The analysis was performed using the Sawtooth Software's CBC/HB module. As mentioned previously, the Sawtooth Software has a comprehensive set of built-in commands for estimating discrete choice models and can be used to estimate discrete choice experiments' HB models (Lancsar et al., 2017). The analysis was used for research purposes only.

3.7.4.4. Counting Analysis

A counting analysis was also be performed to obtain a concise ratio-scaled calculation of the main effects and joint effects for the CBC data. Counts estimate the proportion of "wins" for each level, based on how many times a test alternative including that level is selected, divided by the number of times an alternative including that level appeared in the choice task. The size and statistical significance of the main effects were calculated using a default Within Attribute Chi-Square to indicates whether levels of an attribute differ significantly in their frequency of choice. Of note, a main-effect Chi-Square test that was not significant did not necessarily mean that the attribute had little impact on choice, but could rather underlie disagreement between individuals on what level was preferred, which could reduce the impact of an attribute when participants' choices were aggregated. Although the Chi-Square effects reported by Counts might have differed from those computed by Logit, highly significant effects were expected to be similar.

3.7.4.5. Attribute Ranking and Weighting

After being derived at the level of the individual, attribute-level utilities were used to determine the weight of each attribute in each respondent's decision-making. Attribute weight (*S*) was calculated by:

$$S = (\text{Range A}i / \sum_{i-1} \text{Range A}i) \times 100$$

where Range A*i* = (highest part-worth of A*i* minus lowest part-worth of A*i*); n = the number of attributes; and A*i* = *i*th attribute (Wellman et al., 2008). With this computing procedure, the weight of each attribute for an individual participant was directly proportional to the distance between the highest and lowest part-worth utilities for that attribute (Ettinger et al., 2018). Relative importances were then summarized both as ranks and attribute weight. Statistical significance was measured using an independent t-test (Altman, 1990). Although the ranking and weighting technique has received criticism, it has been described to provide reasonable approximations and useful representations of results (Flynn et al., 2008).

3.7.4.6. Market Simulations

Accounting for relative preferences or utilities alone can mask important decision-making information. Given that the extent to which individuals like a product is reflected by the total of the utility values for the attribute levels that describe a product, conducting a market simulation is useful because they can be used to reflect real-world possibilities (Orme, 2010). This analysis extension can use utilities calculated from HB estimations to simulate having all participants gathered together to vote on the test alternative they prefer, and therefore to be able to apply this information predict which cardiovascular imaging test would be preferred in clinical settings (Orme, 2010).

Using a randomized first choice simulation method to allocate share to each of the simulated options and a sequential sensitivity analysis as range behavior to account for dynamic fields (ranges) in the scenarios, shares of preferences were estimated in both patient and physician participants. This technique assumed the participants chose the product with the highest overall utility, but it added unique random error to the utilities in a way that each participant was sampled multiple times to stabilize the share estimates, while correcting for product similarity caused by correlated sums of errors among products defined on several of the same attributes (Orme & Heft, 1999). Current test alternatives described in Table 5 were introduced within the simulated market scenarios and the simulation reported the projected percentage of participant that would choose a test over the others according to the previously calculated HB utilities and trade-offs.

Table 5

Comparison of Test Alternatives of Interest for Market Simulations

Imaging Tests	Type of procedure	Test duration	Patient out-of-pocket cost	Type of scanner	Risks and side effects	Diagnostic accuracy
Stress Perfusion CMR	Pharmacological agents	60 minutes	$1500	Complete body scanner	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications	90%
Exercise Echo	Exercising	30 minutes	$500	No scanner	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications	80%
Pharmacological Stress Echo	Pharmacological agents	30 minutes	$500	No scanner	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications	80%
CTA	N/A	30 minutes	$500	Partial body scanner	Exposure to radiation and a 0.1% possible increase in cancer risk	80%
SPECT	Pharmacological agents	60 minutes	$1000	Partial body scanner	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications	70%
PET	Pharmacological agents	60 minutes	$2000	Partial body scanner	Chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications	90%
b-CMR	Breathing maneuvers	30 minutes	$1000	Complete body scanner	Tingling in the fingers, dizziness and dry mouth	80%

In addition, the results of the conjoint analysis may be used to assess the price elasticity of health care products and the users' willingness to pay (WTP) for certain services. WTP is typically

measured in terms of money and is a characteristic of buyers or consumers that illustrates how much value a consumer places on a service or product. Discrete choice experiments have been used to estimate participants' WTP for a variety of health-related applications (Roy et al., 2015). In the current DCE, trade-offs between cost and diagnostic accuracy and between risks and side effects were computed while holding other attributes constant. In addition, common cardiovascular diagnostic tests were combined to estimate imaging modality-specific shares of preferences.

3.7.4.7. Subgroup Analysis

Comparing patient and health professional preferences for health-related interventions has been an important topic in DCE literature. To understand subgroup differences in preferences for health services, investigations of heterogeneity of preferences within groups have been recommended (Harrison et al., 2017). Therefore, a comparison of main effects was performed between patients' age (above vs below 60 years of age) gender (male vs female), language (French vs English), education level (elementary or high school education vs college or university degree) and income (below vs above 50 thousand dollars per year) subgroups.

4. RESULTS

4.1. PARTICIPANTS' CHARACTERISTICS

Table 6 compared patient and physician respondents. A total of 211 participants returned the survey and were included in the analysis. One hundred and seventy-three eligible patients consented to the study, but 148 returned the questionnaire and were included in the analysis, representing an 89.4% response rate. Most of the participants who consented but did not return their questionnaire were called for their clinical appointment and left without giving their questionnaire back to the researcher. Physicians' response rate could not be calculated due to previously described online recruitment procedures. A total of 63 physicians consented to the study and completed the questionnaire with partially or fully completed choice scenarios.

Table 6

Demographic Characteristics

		Patients (%)	**Physicians (%)**
Sample size		N = 148	N = 63
Age			
	Mean	54.2	49.0
	Standard deviation	18.2	11.1
Gender			
	Male	79 (53.7)	40 (63.5)
Language			
	English	71 (48.0)	59 (93.7)
	French	77 (52.0)	4 (6.3)
Education			
	Elementary school	8 (5.4)	0 (0.0)
	High school	48 (32.7)	0 (0.0)
	College	33 (22.4)	0 (0.0)
	University	51 (34.7)	63 (100.0)
	No answer	7 (4.8)	0 (0.0)

Yearly income		
Less than $25 000	20 (14.0)	0 (0.0)
$25 000 to $49 999	34 (23.8)	0 (0.0)
$50 000 to $74 999	17 (11.9)	0 (0.0)
$75 000 to $99 999	15 (10.5)	0 (0.0)
$100 000 to $149 999	19 (13.3)	1 (1.6)
	13 (9.1)	52 (82.5)
More than $150 000	25 (17.5)	10 (15.9)
No answer		
Familiarity with imaging modalities		
At least one modality	134 (91.2)	62 (98.4)
MRI	96 (65.3)	56 (88.9)
Echography	111 (75.5)	61 (96.8)
CT	44 (29.9)	56 (88.9)
SPECT	5 (3.4)	47 (74.6)
PET	14 (9.5)	43 (68.3)
Experience/Ordering with imaging modalities		
At least one modality	124 (84.4)	61 (96.8)
MRI	77 (52.4)	31 (49.2)
Echography	97 (65.5)	45 (71.4)
CT	38 (25.7)	46 (73.0)
SPECT	3 (2.0)	29 (46.0)
PET	9 (6.1)	20 (31.7)
Questionnaire difficulty		
Very easy	24 (17.5)	10 (17.2)
Easy	56 (40.9)	18 (31.0)
Not easy, not difficult	51 (37.2)	25 (43.1)
Difficult	6 (4.4)	5 (8.6)
Very difficult	0 (0.0)	0 (0.0)
Medical specialty	N/A	
Cardiologists		29 (46.0)
Family physicians		34 (54.0)

4.1.1. Patients' Characteristics

One hundred and forty-eight cardiac patients aged between 19 and 85 years and admitted to the Royal-Victoria Cardiology Clinic completed the pen-and-paper DCE questionnaire. Mean age of patients was 54.2 (± 18.2 years). Patients were 53.7% males, and about half of them (52.0%) preferred to answer the French version of the questionnaire. Patients highest level of education varied between elementary school (5.4%), high school (32.7%), college or technique (3-year program) (22.4%), university (34.7%) and 4.8% patients preferred not to report their education. In terms of income, 14.0% of patients reported making less than 25 000 dollars in income last year, 23.8% made between 25 000 and 49 999 dollars, 11.9% made between 50 000 and 74 999 dollars, 10.5% made between 75 000 and 99 999 dollars, 13.3% made between 100 000 and 149 999 dollars, 9.1% made more than 150 000 dollars, and 17.5% preferred not to answer this question.

In addition, most patients (91.2%) were familiar with at least one advanced cardiovascular imaging test, including MRI (65.3%), echography (75.5%), CT (29.9%), SPECT (3.4%) and PET (9.5%). Similarly, most cardiac patients (84.4%) reported to have experienced at least one advanced cardiovascular imaging test, including MRI (52.4%), echography (65.5%), CT (25.7%), SPECT (2.0%) and PET (6.1%).

Most patients (58.4%) found the questionnaire "very easy" (17.5%) or "easy" (40.9%). The questionnaire was considered "not easy, not difficult" by 37.2% of patients, and 4.4% found it "difficult". None of the patients found the questionnaire "very difficult". There was no significant association between patients' reported questionnaire difficulty and highest education level, gender, and familiarity with cardiovascular imaging tests. There were significant relationships between difficulty and age ($r = 1.91$, $n = 135$, $p = 0.027$). Older participants found the questionnaires more difficult than younger participants. There was also a significant difference in the scores for French respondents ($M=2.45$, $SD=0.80$) and English respondents ($M=2.10$, $SD=0.78$) conditions; $t(135)=2.60$, $p = 0.010$. French respondents generally found the questionnaire more difficult than their English counterparts.

4.1.2. Physicians' Characteristics

Sixty-three physicians aged between 27 and 70 years completed the online DCE questionnaire. The mean age for physicians was 49.0 (± 11.1 years). The physician group included 29 cardiologists and 34 family physicians, of which 63.5% were males, and 93.7% preferred answering the questionnaire in English. Most physicians (82.5%) reported making more than 150 000 dollars in income last year, 1.6% made between 100 000 and 149 999 dollars, and 15.9% preferred not to report their yearly income.

Only one physician respondent reported not to be familiar with any advanced cardiovascular imaging test. Others were at least familiar with MRI (88.9%), echography (96.8%), CT (88.9%), SPECT (74.6%), and with PET (68.3%). Almost all physicians (96.8%) reported to have ordered at least one advanced cardiovascular imaging test for their patient. About 50% reported having ordered an MRI, 71.4% an echography, 73.0% a CT, 46.0% a SPECT, and 31.7% have ordered a PET.

The questionnaire was considered "not easy, not difficult" by 43.1% of physicians. Others found it "very easy" (17.2%), "easy" (31.0%), or "difficult" (8.6%). None of the physicians found the questionnaire "very difficult". There was no significant association between physicians' reported questionnaire difficulty and gender, age, language, familiarity with cardiovascular imaging tests, and medical specialty.

4.2. CHOICE-BASED CONJOINT ANALYSES

4.2.1. Counting Analysis

Of the 211 eligible participants who returned the DCE questionnaire, 190 (90.0%) completed all the choice-based conjoint scenarios. The counting analysis revealed significant attribute main effects in both patients and physicians (Table 7). In patients, significant attribute

main effects included risks and side effects (χ^2=157.7, p<0.01), diagnostic accuracy (χ^2= 60.273, p<0.01), and cost (χ^2= 44.298, p<0.01), while type of scanner (χ^2= 3.478), type of procedure (χ^2= 3.452) and test duration (χ^2= 1.954) had no significant main effects. In physicians, four main effects were observed: Cost (χ^2= 30.558, p<0.01), diagnostic accuracy (χ^2= 25.562, p<0.01), risks and side effects (16.913, p<0.01), and type of procedure (χ^2= 10.303, p<0.01). Counting analysis revealed no significant main effects for the type of scanner (χ^2= 2.393) and the test duration (χ^2= 0.570) attributes.

Table 7

Counting Analysis

Test Attributes	Main Effects	
	Patients	**Physicians**
Risks and side effects	χ^2=157.7, p<0.01	χ^2= 16.913, p<0.01
Diagnostic accuracy	χ^2= 60.273, p<0.01	χ^2= 25.562, p<0.01
Patient out-of-pocket cost	χ^2= 44.298, p<0.01	χ^2= 30.558, p<0.01
Type of scanner	χ^2= 3.478, not significant	χ^2= 2.393, not significant
Type of procedure	χ^2= 3.452, not significant	χ^2= 10.303, p<0.01
Duration	χ^2= 1.954, not significant	χ^2= 0.570, not significant

4.2.2. Hierarchical Bayes Estimation

The CBC/HB estimation revealed diverging attribute utilities between patients and physicians. Table 8 describes results from the CBC/HB estimation.

Table 8

Hierarchical Bayes Analysis

Test Attributes	Levels	Patients		Physicians	
		Relative Importance	**Zero-centered Utilities**	**Relative Importance**	**Zero-centered Utilities**

Risks and side effects		**30%**		**19%**	
	Possible tingling in the fingers, dizziness and dry mouth		97.71		56.54
	Possible chest pain, irregular heartbeat, flushing, breathing difficulties, and a 0.1% chance of serious complications such as a heart attack		-61.04		-25.40
	Exposure to radiation and a 0.1% possible increase in cancer risk		-36.66		-31.14
Diagnostic accuracy		**25%**		**22%**	
	90%		71.41		39.62
	80%		-5.91		23.18
	70%		-65.50		-62.81
Patient out-of-pocket cost		**22%**		**29%**	
	$500		63.29		83.90
	$1000		10.76		17.83
	$1500		-8.57		-21.67
	$2000		-65.48		-80.06
Type of procedure		**10%**		**11%**	
	Breathing maneuvers		6.91		-6.21
	Exercising		16.04		-2.434
	Pharmacological agents		-22.95		8.65
Type of scanner		**8%**		**9%**	
	No scanner		-1.47		4.22
	Partial body scanner		-1.16		0.64
	Complete body scanner		2.63		-4.86
Test duration		**5%**		**10%**	
	30 minutes		5.45		16.95
	60 minutes		-5.45		-16.95

4.2.2.1. Average Utilities (Zero-Centered Differences)

Figure 9 displayed zero-centered utilities for each attributes' levels. Patients placed high utilities (+97.71) to tests with milder side effects such as tingling in the fingers, dizziness and dry mouth but avoided choosing tests involving exposure to ionizing radiation (-36.66) and risks associated with exercise and the use of pharmacological agents inducing direct coronary arteriolar vasodilation (-61.04). Patients also valued more accurate tests (+71.41) than less accurate tests (-65.50), and less costly tests (+63.29) than more costly tests (-65.48). There was not a statistical difference in level utilities in the type of procedure (+6.91 vs -22.95), type of scanner (+2.63 vs -1.47) and test duration attributes (+5.45 vs -5.45). Physicians, on the other hand, placed high utilities to less costly tests (+83.90), and low utilities to more costly tests (-80.06). They also valued

more accurate tests (+39.62) than less accurate tests (-62.81), and tests with milder risks and side effects (+56.54) than tests with ionizing radiation (-31.14) and those with increased risks and side effects (-25.40).

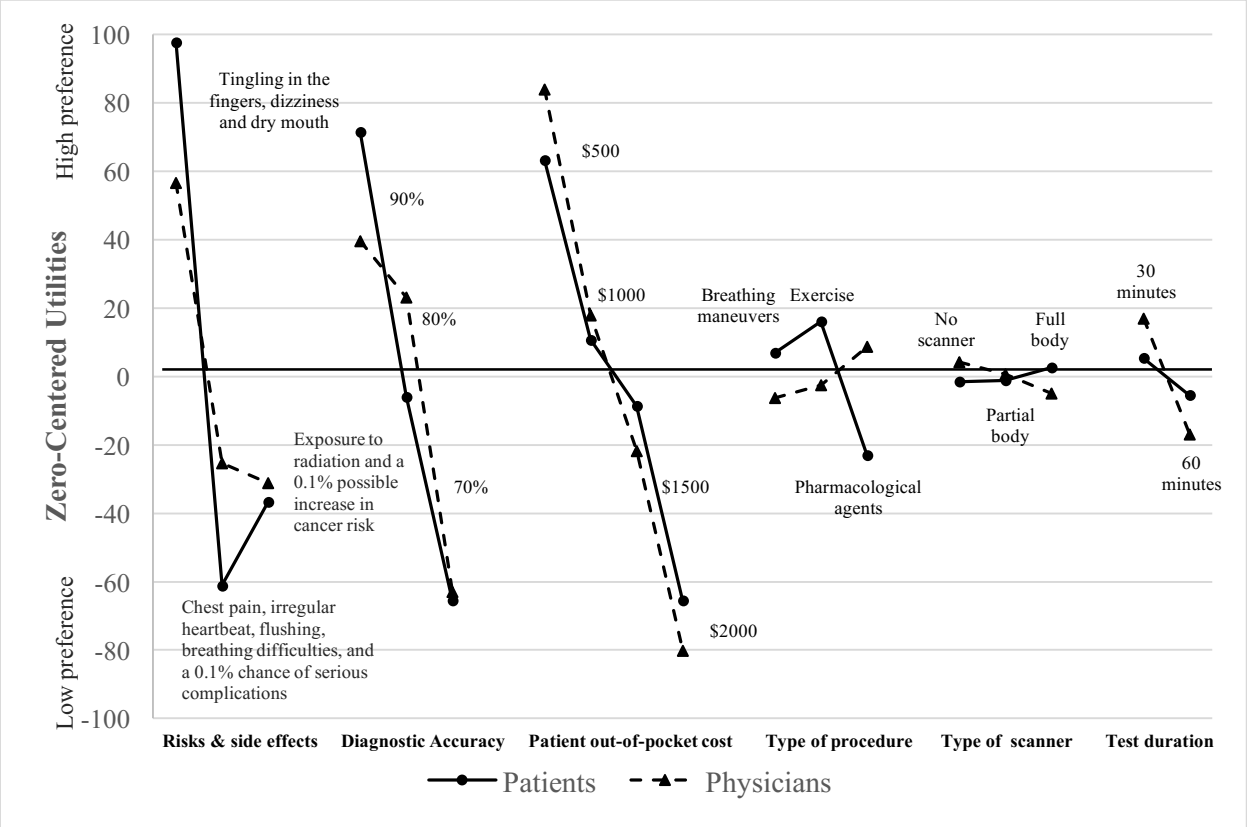

Figure 9. Hierarchical Bayes Zero-Centered Utilities.

4.2.2.2. Attribute Ranking, Weighting, and Relative Importances

The relative weight, or importance in treatment decisions of each attribute, was compared between participant groups. Attribute relative importances and zero-centered utilities were described in (Figure 10).

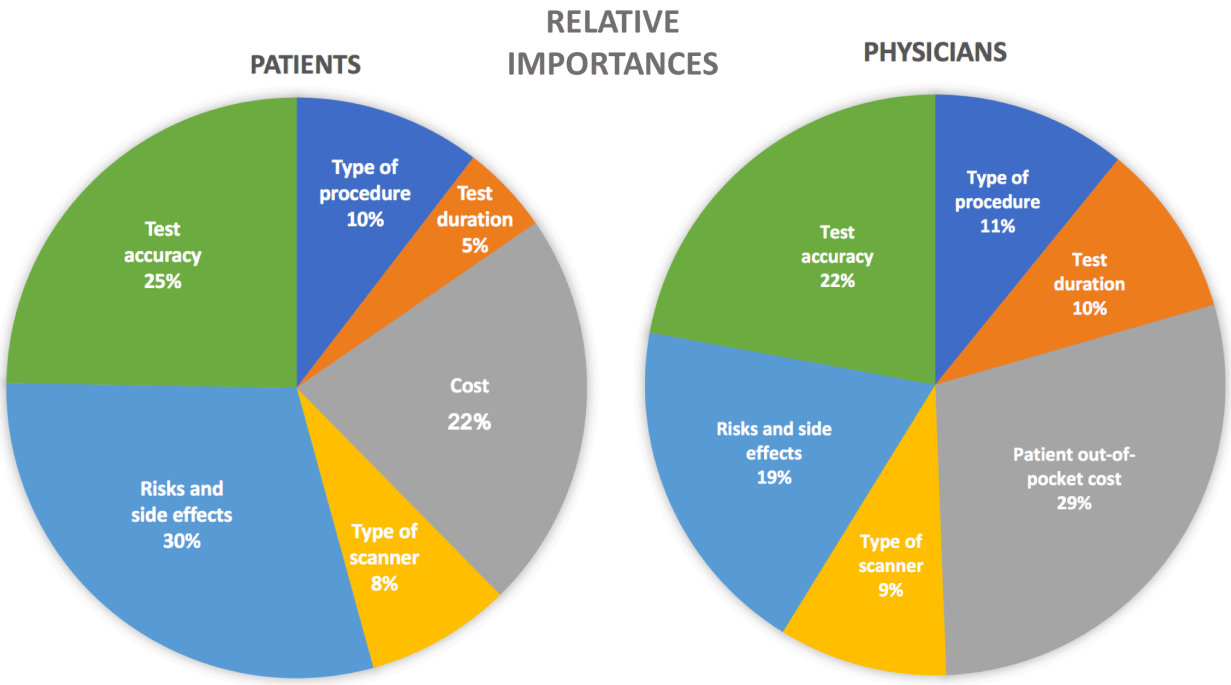

Figure 10. Relative Importances of test attributes.

In terms of ranks and attribute importances, patients and physicians had the same top three attribute priorities (Figure 11). Patients ranked risks and side effect as first and most impotant (30%), and ranked diagnostic accuracy (25%) and cost second and third (22%), respectively. Physicians ranked cost first (29%), also ranked diagnostic accuracy second (22%), and risks and side effects third (19%). Type of procedure was ranked fourth for both patients (10%) and physicians (11%). Type of scanner and test duration were ranked fifth (8%) and sixth (5%) for patients, and sixth (9%) and fifth (10%), respectively, for physicians. None of the percentage differences in CBC/HB relative importance ranks were statistically significant.

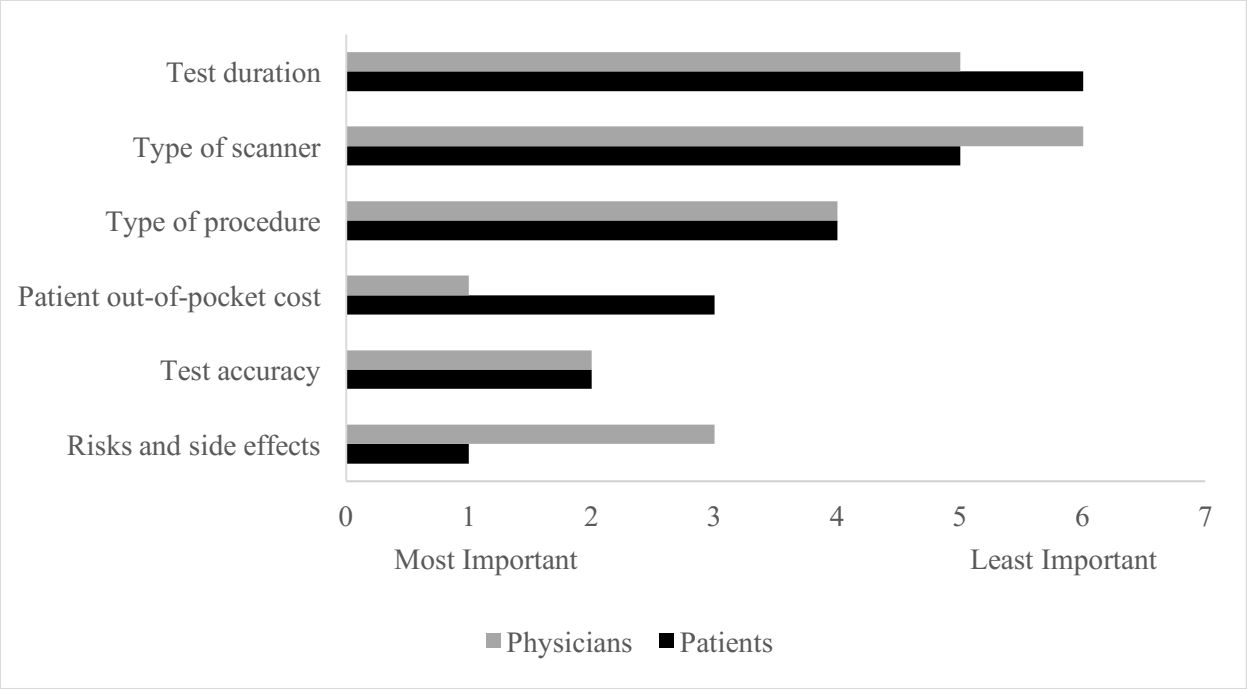

Figure 11. Relative rank of test attributes for test decision-making.

Unlike the attribute ranking and importance analyses, the attribute weight analysis revealed significant differences between patient and physician preferences (Figure 12). Risks and side effect has a significantly greater decision-making weight for patients that for physicians (33.8% vs 21.3%, $p < 0.05$), with patients placing significantly less weight on the cost attribute than physicians (27.4% vs 39.8%, $p < 0.005$). Other differences in attribute weights were not statistically significant.

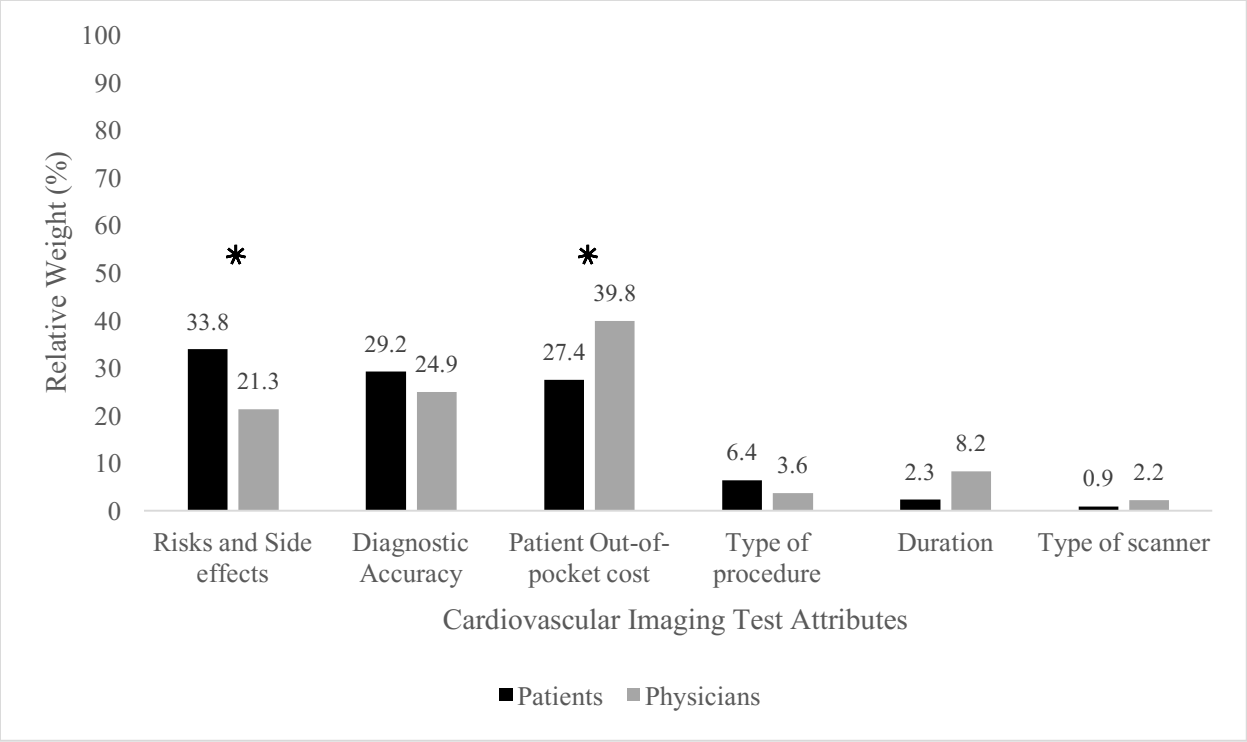

Figure 12. Comparison of test attribute relative weight in decision-making. *Denotes a significant difference in attribute weight between patient and physicians ($p < 0.05$).

4.2.2.3. Market Simulation & Sensitivity Analysis

As mentioned previously, a market simulation was conduction comparing characteristics of common cardiovascular imaging tests (Figure 13). Shares of preferences in both patient and physician groups were higher for characteristics related to b-CMR. It was estimated that 59.6% of cardiac patients and 32.7% would prefer b-CMR over other diagnostic imaging tests. Patients ranked exercise echo second (12.8%), and stress perfusion CMR (11.9%) third. Conversely, physicians ranked pharmacological stress echo second (25.0%), and CT (17.1%). Both groups placed the lowest shares of preferences to SPECT.

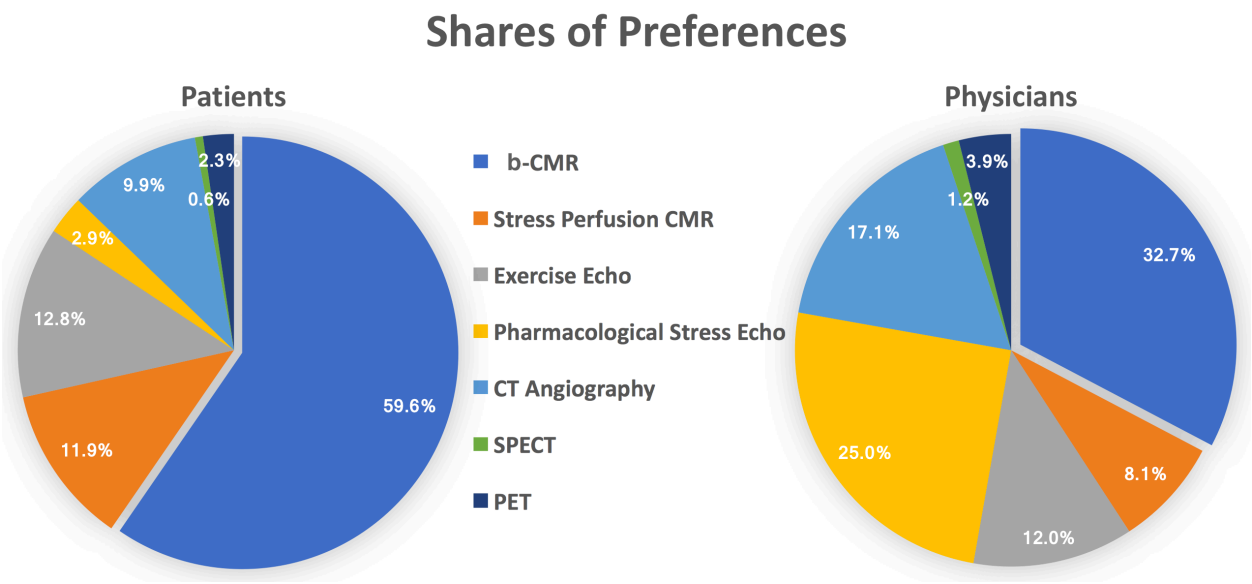

Figure 13. Shares of preferences for cardiovascular imaging tests.

4.2.2.3.1. Trade-offs between risks and diagnostic accuracy

When holding other attributes constant, a sensitivity analysis revealed that about 42.7% of patients would sacrifice diagnostic accuracy to avoid tests with exposure to ionizing ration and those associated with exercise and the use of pharmacological agents inducing direct coronary arteriolar vasodilation (Figure 14).

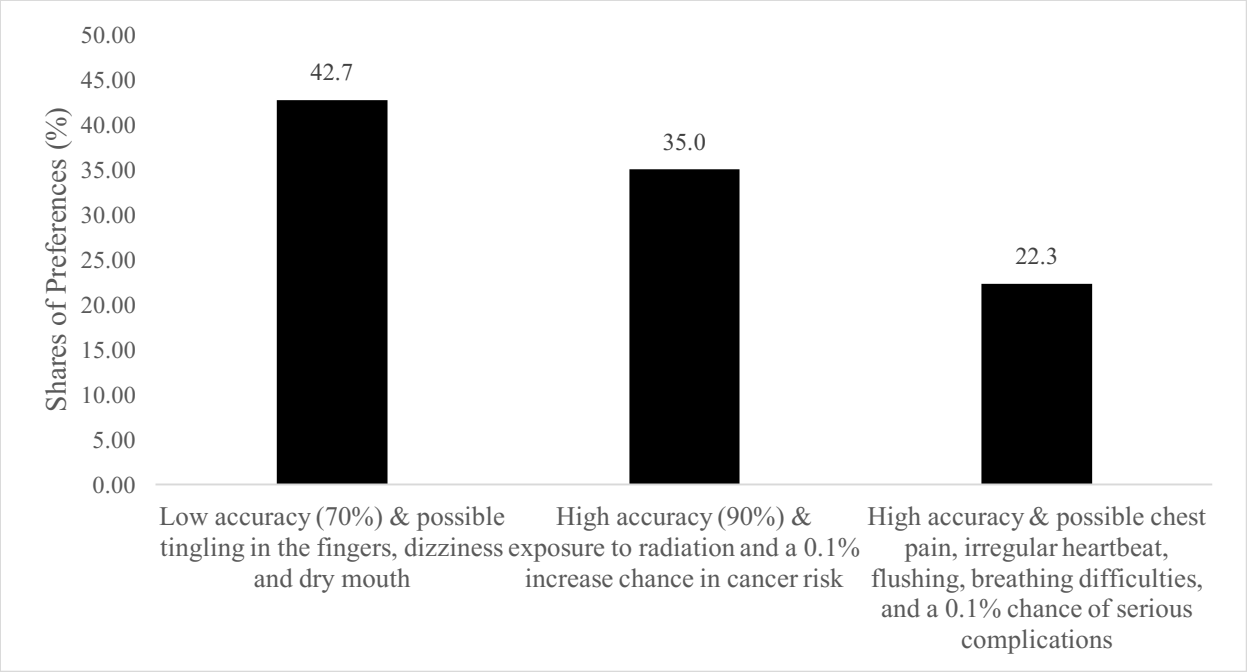

Figure 14. Patient trade-off between diagnostic accuracy & risks and side effects.

4.2.2.3.2. Trade-offs between risks and cost

Similarly, when holding other attributes constant, a sensitivity analysis on risks and side effects and cost showed that 43.3% of patients would be willing to pay more for a test with milder side effects (Figure 15).

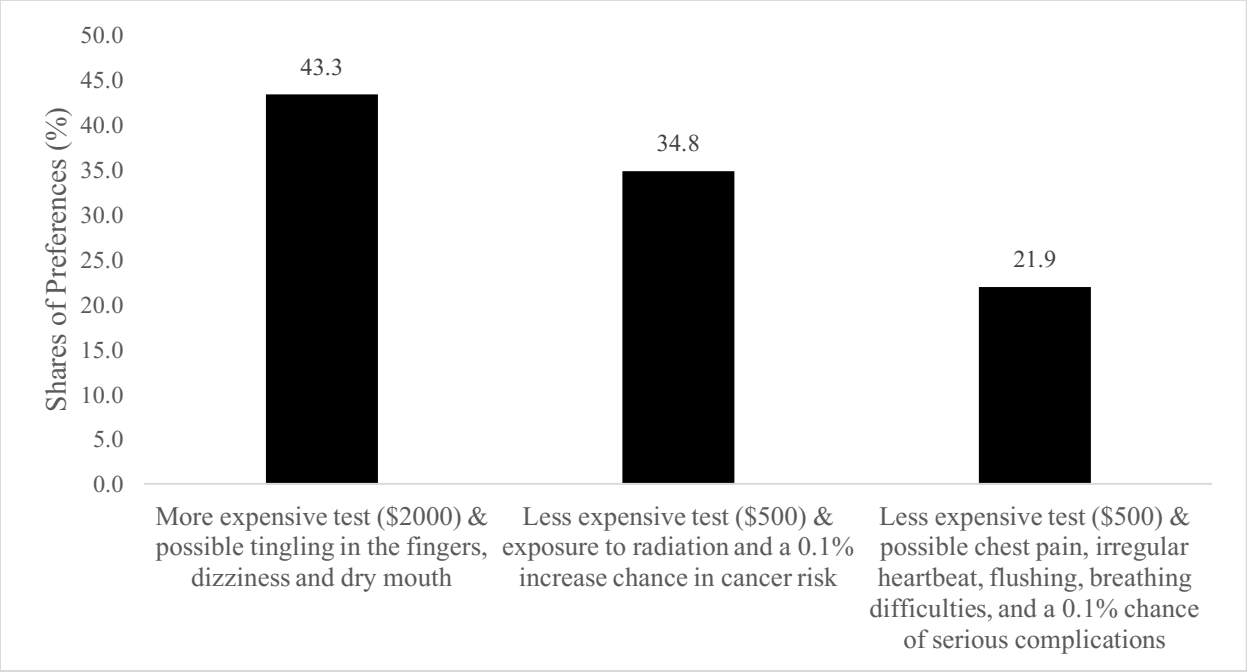

Figure 15. Patient trade-off between cost & risks and side effects.

4.2.2.3.3. Modality-specific preferences

Shares of preferences for common cardiovascular tests and grouping them with their respective imaging modality were combined in figure 16. Both patients and physicians preferred CMR over other modalities, with 71.5% and 40.8% of shares respectively. Patients and physicians placed echocardiography second (15.7% vs 37%.0), and CT third (9.9% vs 17.1%). Both groups ranked nuclear imaging tests last (patients: 2.9%, physicians: 5.1%).

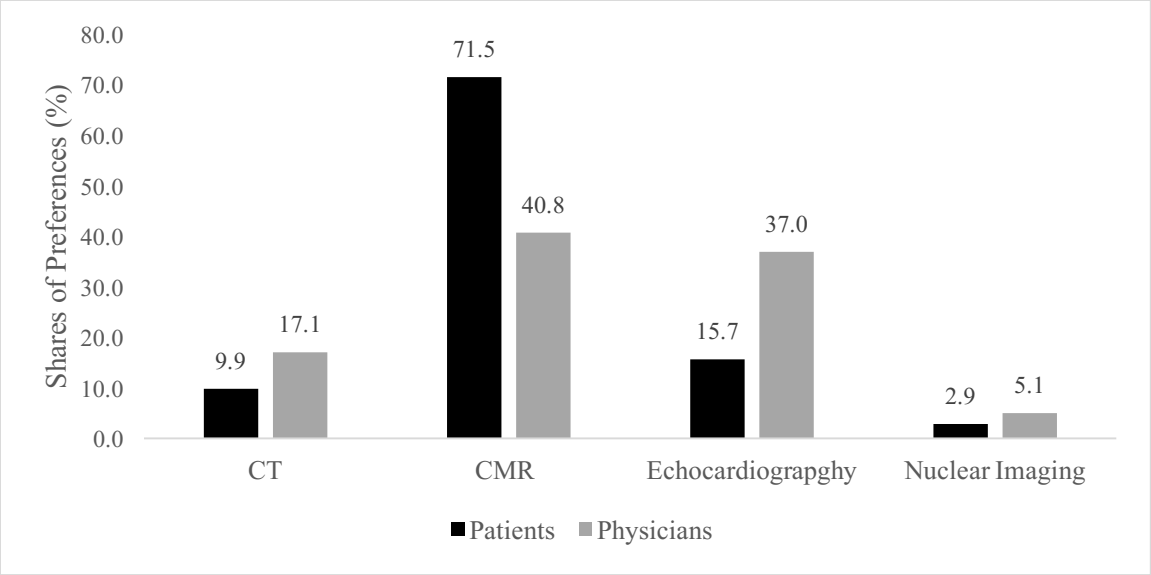

Figure 16. Modality-specific shares of preferences.

4.2.3. Subgroup Analysis

Binomial subgroup analyses of attribute main effects were performed in patients' age, education, income, gender, and language. Patients making less than $50 000 income per year place more importance on risks and side effects than patients making $50 000 or more (Between Group χ^2= 13.862, $p<0.01$). There were no other statistically significant differences in attribute preferences in patient subgroups. Nonetheless, there was a tendency for younger patients (59 years or less) to put more emphasis on cost (χ^2= 35.915, $p<0.01$) than their older counterparts (60 years or more) (χ^2= 9.915, $p<0.05$).

5. DISCUSSIONS

This study is the first to estimate patients' and physicians' preferences for attributes of cardiovascular tests and imaging modalities used for diagnosing coronary heart disease and to quantify the value of combined imaging test features with the use of a discrete choice experiment. Similar to most studies comparing patient and physician preferences in a DCE (Harrison et al., 2017), our results showed mixed concordance and discordance between groups. Although patients and physicians generally agreed on the importance of risks and side effects, diagnostic accuracy and patient out-of-pocket cost relative to other attributes, the order of these importances differed. When given the choice, cardiac patients' preference was mostly determined by the risks and side-effects associated with cardiovascular imaging tests. Patients preferred tests with mild side effects such as tingling in the fingers, dizziness and dry mouth, but avoided test alternatives with exposure to ionizing radiation and risks associated with exercise and the use of pharmacological agents inducing direct coronary arteriolar vasodilation. Conversely, physicians most valued tests of lower cost to their patient. Our findings compare favorably with previous DCE studies showing that patients prefer a treatment with minimized side effects (Hauber et al., 2013; Clark et al., 2014; Harrison et al., 2014; Harrison et al., 2015). Our results were also in line with a review on DCEs comparing patient and physician preferences that reported that process attributes, such as treatment risks and side effects, were more important to patients (de Bekker-Grob et al., 2013; Harrison et al., 2017; Ettinger et al., 2018) and that economic considerations played an important role in physicians' treatment decisions (Hifinger et al., 2016). Following a subgroup analysis, unexpected findings showed the risks and side effects attribute was especially important to patients making less than $50 000 income per year, when compared to those making $50 000 or more. As health literature on income and risk aversion is sporadic, this subgroup finding remains difficult to explain (Friedman, 1974; Holt & Laury, 2002).

Diagnostic accuracy was ranked second in importance for both patients and physicians and the relative weight of this attribute was comparable in both participant groups. However, results from many DCEs in healthcare have shown that efficacy or diagnostic accuracy was more important to participants than safety or risk-related attributes (Hiligsmann et al., 2014;

Ingvarsdottir et al., 2016; Ettinger et al., 2018). Although our review of literature allowed us to include a realistic representation of advanced cardiovascular non-invasive imaging tests for diagnosing CAD, it is possible that participants did not find the difference between 70% and 90% accuracy as substantial as differences in the risk attributes or in the costs. Adding more information on the prognostic aspect in the description of this attribute and more clarity on what requirements for further testing following inaccurate testing would entail for patients might have increased the preference weight allocated to diagnostic accuracy. Both groups were less influenced by the test duration, type of procedure and type of scanner when making their decision between test alternatives. The reduced relative importances associated with these three attributes may be rationalized by their more indirect effects

Unlike general trends in DCE studies where patients attributed more importance to cost attributes than physicians (Lee et al., 2015; Harrison et al., 2017), our results showed that cost was more important to physicians. This could be explained because, in Canada, the universal healthcare system allows patients to not have to pay for their cardiovascular imaging tests. It is possible that physicians overestimated the importance of cost to their patients. Nevertheless, in Canada, physicians are limited to certain number of scans performed for their patients due to cost containments. It is possible that physicians considered costs as very important because they esteemed and aimed to enforce these limits. Furthermore, with reports of issues related to increasing healthcare costs and associated concerns to patients and the healthcare system (Blumenthal, 2001; Berwick & Hackbarth, 2012), educational programs and leading physician associations tend to highlight the importance of providing high-value and cost-conscious care (American College of Physicians, 2014). Being educated and thus critically aware of the importance of considering cost in their medical practice may explain why physicians highly valued this attribute (Stammen et al., 2015).

Contrasting Dong et al.'s (2016) findings on patients' preferences for pharmacogenetic testing to reduce severe adverse drug reaction, results from the current study showed that most patients would not be willing to trade-off side effects for less costly test alternatives. Similarly, most patients in this study would not accept to trade-off risks and side effects for tests with higher diagnostic accuracy. This strong preference for avoiding risks and side in diagnostic tests may be

explained because these tests are not meant to treat diseases, but rather help to identify it (Nishimura et al., 2014). Knowing that medical treatments could directly & positively influence their health (as opposed to diagnostic tests which may have more indirect benefits), patients may be more willing to trade-off risks associated with these treatments (Crawford, 2017). The discordance of importance assigned to the risks and side effects attribute between patients and physicians may also be rationalized by the greater perceived risks associated with diagnostic tests in patients. For trained physicians commonly ordering diagnostic tests, 0,1% chances of complication may seem rare when compared to more risky procedures such as ICA.

The market simulation was performed by associating current imaging tests with their closest matching attribute levels as revealed by literature. The simulation revealed the b-CMR test had the highest shares of preferences in both patients and physicians. This could be explained because b-CMR has been associated with features that were associated with higher utility, and especially because of its lack of undesirable features. Given the high importance of the risks and side effects attribute in patients, this result was not surprising because b-CMR was the only test associated with the tingling in the fingers, dizziness and dry mouth level, which had the highest utility of all levels in both participant groups. In physicians, b-CMR did not have the preferred levels for the cost and diagnostic accuracy attributes, but it remained the overall preferred test because of its absence of undesirable characteristics in all important attributes combined. Inversely, our results did not fully correspond to reports from the American Society of Nuclear Cardiology that stated PET had "[…] effective, safe, efficient, patient-centered, equitable, and timely […]" imaging properties (Bateman et al., 2016). Instead, when compared to other current cardiovascular imaging tests, the market simulation allocated the lowest shares of preferences to nuclear imaging alternatives. Our results did not dispute the patient-centeredness of nuclear medicine in cardiovascular imaging, but when compared to other current imaging tests, nuclear imaging tests tended to have less desirable properties.

5.1. LIMITATIONS

There are limitations worthy of attention in this study. First, the physician sample contained a large proportion of male participants, which may have inadvertently introduced sample bias. We attributed this to the existence of gender differences in the manifestation of cardiologists, wherein the male gender is more common amongst Canadian cardiologists (Canadian Medical Association, 2015). Because subgroup analyses of the patient sample did not reveal preference differences between males and females, the male overrepresentation in the physician sample was, likewise, not expected to considerably affect results. Second, in comparison with the patient sample, the physician sample was overrepresented by English speakers. As most physician participants were affiliated with the MUHC, a primarily Anglophone medical and education center, this language disparity was expected. Although it is difficult to estimate the extent of the bias this discrepancy might have introduced to the physician sample, the language subgroup analysis of the patient participants did not reveal any language differences in attribute preferences, and thus similar results could be expected for the physician sample. Of note, the subgroup analyses were only performed on the patient sample because it was estimated that the physicians sample was not sufficiently large to perform higher order analyses (Lancsar & Louviere, 2008). As previously mentioned, most DCE studies (73%) have a sample size with fewer than 300 participants (de Bekker-Grob et al., 2015). This study enrolled a total of 211 participants, which has been considered sufficiently large for DCE designs (Pearman et al., 2000; Hall et al., 2004; Lancsar & Louviere, 2008). When considering participant groups separately, the patient sample included a minimum of 20 participants per questionnaire version, but not the physician sample, which included an average of 9 participants per questionnaire version. Thus, when analyzed separately, the strength of evidence would be expected to be higher in the patient sample than in the physician sample (Johnson et al., 2013). In addition, this study was performed in a Canadian environment, and it would, therefore, be challenging to estimate how these results would be applicable in other countries with very dissimilar healthcare systems. For instance, participants in countries that do not have access to universal healthcare such as the United-States may respond differently to the cost attribute. The results can be considered relevant to other universal coverage systems that exist in high income countries such as Great Britain.

A strength of this study was that both participant samples completed the same version of the questionnaire and data were treated with the same methods of analysis. Hence, unlike many

DCEs comparing patient and health professional preferences, divergences were more likely to be attributable to genuine differences between groups (Harrison et al., 2017). However, for practical reasons, patients completed pen-and-paper questionnaires while physicians completed web-based questionnaires. Although both types of survey methods had identical questions for all seven questionnaire versions, it is possible that the differing questionnaire administration methods contributed discordances between participant samples but this would be minimal.

In addition, as mentioned previously, both groups received the same instructions, including: "Imagine you had to choose a cardiovascular imaging test (for the patient) in a private clinic", and with the following prompt before each choice task: "Please select which type of test you prefer by considering each test characteristics. Select Test A or Test B". Thus, physicians were asked to answer choose the best test for their patient from their individual perspective. However, to be more realistic, the cost attribute was framed as "patient out-of-pocket cost", which might have influenced physicians to answer the choice tasks from the perspective of their patients, rather than their own and thus systematically avoid more expensive test alternatives (Anderson et al., 2014). Nonetheless, in the context of cancer care, only a few physicians reported omitting treatment options on the basis of their perceptions of patients' ability to afford treatment (Schrag & Hanger, 2007). Another important limitation related to the choice of adding a cost attribute was that in Canada, Medicare covers most medical exams and patients generally do not pay for these medical services. However, to reduce this limitation, researchers clearly instructed participants that the cost attribute was to be understood as though patients had to pay for their imaging test, similar to uninsured services from a private clinic.

The market simulation offered a more applied and concrete representation of the CBC/HB results (Orme, 2010). However, as mentioned previously, these results were only as precise as the attributes and levels used to describe the real test alternatives. While most important imaging tests' attributes were determined through literature review, interviews and group discussions with key informants in the context of cardiology, these methods do not guarantee that we have included tests' attributes that are relevant to our participants' preferences. Having added more test attributes might have provided more precise information to characterize the current imaging tests compared. Although the precision of cardiovascular diagnostic imaging tests is often described in sensitivity

and in specificity, for feasibility purposes, these two measures were merged into diagnostic accuracy, a more general quantification of test precision. As some imaging tests are known to be very high in sensitivity or in specificity but to be lower in the other, using the diagnostic accuracy measure balanced its precision properties. Having separated the diagnostic accuracy attribute into sensitivity and specificity might have resulted in different conclusions, but may have added a difficulty component to the questionnaire, especially for the patient group. In addition, features associated with current cardiovascular imaging tests were limited by the levels within attributes, and adding more levels within the chosen ranges might have provided more precise results. For instance, although CTA has been associated with a 77% diagnostic accuracy in Danad et al. (2017), we associated this test with its closest related attribute level, 80%. By being adding a 77% diagnostic accuracy level, the market simulation would have been more representative of Danad et al.'s (2017) report, but the study design could have become more cognitively demanding for participants, thus also affecting results (Bech et al., 2011; Clark et al., 2014).

Furthermore, the market simulation did not allow to add more than one level per attribute for imaging tests. In the case of nuclear imaging tests that are associated with exposure to ionizing radiation and risks associated with exercise and the use of pharmacological agents inducing direct coronary arteriolar vasodilation, this prevented us to create an appropriate representation of PET and SPECT. The simulation for these tests was performed by including only the "chest pain, irregular heartbeat, flushing, breathing difficulties, and a (0.1%) chance of serious complications" level. Nonetheless, while shares of preferences for nuclear imaging tests would have been lowered by the addition of the exposure to radiation level, these only accounted for a minor part of the total shares of preferences. Thus, this underrepresentation of the risks and side effects attribute of nuclear imaging tests potential had at most a negligible effect on the randomized first choice simulation. Additionally, there was no published data about b-CMR's diagnostic accuracy at the time this study was written, but early evidence supported its association with the 80% diagnostic accuracy level in the market simulation. Future research may support this estimation, but it may also be closer to 70% or 90%, which would affect how shares of preferences could be distributed across iterations.

Discrete choice experiments have been criticized as difficult for participants to understand to complete (Adams et al., 2015). To minimize the risk of not being to complete the questionnaire because of its complexity, substantial development work was conducted. As a result, a large majority of participants found the questionnaire either "easy" or "very easy", very few participants found the questionnaire "difficult", and none of the participants found the questionnaire "very difficult". This indicated a good understanding of the DCE in participants. In addition, DCEs have been criticized because their predictive value may be restricted by their quantitative assessment of stated choices rather than actual behavior, which may inherently differ (de Bekker-Grob et al., 2014). Although instinctively different, it is generally assumed that the stated choices are congruent with revealed decisions that would be taken in similar situations in real life (Lambooij et al., 2015). Another basic assumption suggests that people base their choices on latent preferences and intend to maximize their utility (Louviere et al., 2000). Generally, DCEs are recognized to have predictive value, external validity, and have been increasingly used in health research (de Bekker-Grob et al., 2012; Bansback et al., 2012; Quaife et al., 2018). For example, by comparing patients' stated and revealed preferences, Mohammadi and colleagues (2017) reported that DCEs have external validity in the basis of their power to predict actual behavior in latent tuberculosis infection treatments applications.

Finally, participants were presented with hypothetical test alternatives scenarios. It is possible that their preferences may differ in actual clinical settings and when presented with existent test alternatives. Future research might consider comparing both stated and revealed preference approaches to measure preferences of advanced non-invasive cardiovascular imaging tests. They are also encouraged to add invasive imaging procedures, such as the gold standard ICA, in their model.

5.2. Conclusions in a Clinical Context

Placing value in a patient-centered approach to medicine, this study informed healthcare professionals and policy-makers by contributing to the understanding of patient and physician preferences in relation to the choice of advanced non-invasive cardiovascular tests and imaging

modalities used for diagnosing coronary heart disease. Our results indicated which cardiovascular imaging test attributes, relative to each other, are most important to patients and to physicians and likely to influence their preferences and decision-making, quantified the utilities and trade-offs of imaging alternatives from the perspective of patients and physicians, offered an appraisal of the concordance and discordance between patients' and physicians' preferences for cardiovascular imaging tests, and allowed estimating the shares of preferences toward current non-invasive cardiovascular imaging tests for diagnosing CAD.

Cardiovascular imaging has long been driven with a focus on volume and efficiency, but recent focuses have highlighted the importance of patient-centered imaging practices that prioritize patient safety and effectiveness, which represent sizable changes to the culture of imaging (Einstein et al., 2014). Increasingly in cardiovascular imaging, patients are encouraged to become engaged in their care and accept some responsibility to participate in their care plans. The culture of imaging progressively values safety and satisfaction while encouraging partnership with empowered patients (Ellenbogen, 2013). With the rise of chronic heart disease and the growing shortage of healthcare clinicians, patient-centered medicine has the potential to facilitate patient education and engagement in their care, which has become an essential component of long-term care (DePuey et al., 2012; Walsh et al., 2012).

Using the approach of a DCE allowed the integration and the systematic quantification of users' preferences of cardiovascular imaging tests and allowed to estimate how patients and physicians trade imaging test-related attributes, alongside each other (Ryan, 2004). By contributing to the understanding of patient and physician preferences in relation to the choice of advanced non-invasive cardiovascular imaging tests, this study offers valuable information to guide clinical communication and decision-making toward what is most important to patients. Our findings suggest that patients would be willing to pay more for cardiovascular diagnostic imaging tests with reduced risks and side effects, and support the ACC's recommendations toward creating an accountability framework to more safely drive appropriate imaging utilization (Einstein et al., 2014). Therefore, for the diagnosis of CAD, the combination of test procedures with lower risks and a side effects and more accurate imaging modalities should be encouraged. Healthcare professionals and policy-makers should place a higher value on imaging tests that do not involve

exposure to ionizing radiation and pharmacological procedures. This DCE, suggests that breathing-enhanced CMR (b-CMR) may offer desirable attributes to both patients and physicians. This study may also assist physicians to understand and recognize where there may be discordances between what they consider important and what their patients prefer. Recognizing that PCC is highly valued by patients (van Empel et al., 2010), physicians are encouraged to place more importance to risks and side effects associated with cardiovascular imaging tests, even when this means patients would have to pay more for the tests. As mentioned by Einstein (2014):

> The development of current cardiac imaging technologies revolutionized the practice of cardiovascular medicine by allowing the routine, noninvasive assessment of myocardial perfusion and anatomy. It is now incumbent on the imaging community to create an accountability framework to safely drive appropriate imaging utilization" (p. 1488).

Successful patient involvement is significantly more successful with appropriate patient education that includes a discussion on the existence of test alternatives with their respective positive and negative attributes (ACC, 2015). Ultimately, results from this study suggest that, when engaging in shared decision-making and considering the different cardiovascular imaging test alternatives with their patients, physicians should discuss the risks and side effects associated with these tests.

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Appendix A

Implied Consent for Patients (English Version)

INTRODUCTION
You are invited to participate in a research study entitled *Patient and Physician Preferences for Non-Invasive Cardiac Diagnostic Imaging Technologies: A Discrete Choice Experiment.* This study is being conducted by Thomas Bertrand, MSc student, under the supervision of Dr. Matthias Friedrich and Dr. Gillian Bartlett.

OVERVIEW AND PURPOSE OF THE STUDY
The purpose of this study is to investigate and compare patients' and physicians' preferences toward different characteristics of cardiac imaging tests for diagnosing coronary artery disease. We hope that the study results will contribute to scientific knowledge regarding patient and physician preferences in the field of cardiovascular imaging.

STUDY PROCEDURES
This research will focus on understanding which test features you prefer and see how it can influence your decision-making by answering a questionnaire. The questionnaire will include a variety of questions from which you will need to choose between two test alternatives. You will be asked to select your preferred test alternative. The questionnaire will take approximately 20 minutes to complete.

RISKS ASSOCIATED WITH THE STUDY
There are no foreseeable risks associated with participating in this study.

BENEFITS ASSOCIATED WITH THE STUDY
There is no direct benefit to you for participating in this study.

CONFIDENTIALITY AND RIGHT TO WITHDRAW
This questionnaire will remain completely anonymous and no personal information about you will be collected. The investigators affirm and uphold the principle of the participant's right to privacy and that they shall comply with applicable privacy laws. Your participation to this study is voluntary. Thus, it is your right to decide to participate or not, and your decision will have no impact on the quality of care and services to which you are otherwise entitled.

SHARING STUDY RESULTS
Results from this study will be presented at conferences and published in journals.

FUNDING OF THE STUDY
This study is being funded by internal studentships from the RI-MUHC and the McGill University Faculty of Medicine.

CONFLICT OF INTEREST
The researchers have no conflict of interest to declare.

CONTACT INFORMATION
If you have questions about the study you can communicate with the investigator in charge of the study: Dr. Matthias G. Friedrich 514 934-1934 ext: 34630. For any questions concerning your rights as a person taking part in this study, or if you have comments or wish to file a complaint, you can communicate with the Hospital Complaint Commissioner/Ombudsman at the following number: (514) 934-1934 ext:35655.

REVIEW OF THE ETHICAL ASPECTS OF THE STUDY
The McGill University Health Centre Research Ethics Board reviewed this study and is responsible for monitoring the study.

Appendix B

Implied Consent for Patients (French Version)

INTRODUCTION
Vous êtes invités à participer à une étude de recherche intitulée *Préférence des Patients et des Médecins pour les Technologies Non-Invasive d'Imagerie Diagnostique Cardiaque: Expérimentation de Choix Discrets*. L'étude est menée par Thomas Bertrand, étudiant à la maîtrise et supervisée par Dr Matthias Friedrich et Dr Gillian Bartlett.

BUT DE L'ÉTUDE
Le but de cette étude est de comprendre et de comparer les préférences des patients et des médecins à l'égard des différentes caractéristiques des tests d'imagerie cardiaque pour le diagnostic des maladies coronariennes. Nous espérons que les résultats de l'étude contribueront à la connaissance scientifique des préférences des patients et des médecins dans le domaine de l'imagerie cardiovasculaire.

PROCÉDURES DE L'ÉTUDE
Cette recherche se concentrera sur la compréhension des caractéristiques de test que vous préférez et sur la façon dont elles peuvent influencer votre prise de décision en répondant à un questionnaire. Le questionnaire inclura une variété de questions à partir desquelles vous devrez choisir entre deux alternatives de test. Il vous sera demandé de sélectionner votre alternative de test préférée. Le questionnaire prendra environ 20 minutes à compléter.

RISQUES ASSOCIÉS À L'ÉTUDE
Il n'y a pas de risques prévisibles associés à la participation à cette étude.

BÉNÉFICES ASSOCIÉS À L'ÉTUDE
Vous n'avez aucun avantage direct à participer à cette étude.

CONFIDENTIALITÉ ET DROIT DE REFUS
Ce questionnaire restera totalement anonyme et aucune information personnelle vous concernant ne sera collectée. Les enquêteurs affirment et défendent le principe du droit au respect de la vie privée des participants et qu'ils se conforment aux lois applicables en matière de protection de la vie privée. Votre participation à cette étude est volontaire. Ainsi, vous avez le droit de décider de participer ou non et votre décision et votre décision n'aura aucune incidence sur la qualité des soins et des services auxquels vous avez droit autrement.

PARTAGE DES RÉSULTATS
Les résultats de cette étude seront présentés lors de conférences et publiés dans des revues.

FINANCEMENT DE L'ÉTUDE
Cette étude est financée par des étudiants internes de l'IR-CUSM et de la Faculté de médecine de l'Université McGill.

CONFLITS D'INTÉRÊTS
Les chercheurs n'ont aucun conflit d'intérêt à déclarer.

INFORMATION DE CONTACT
Si vous avez des questions sur l'étude, vous pouvez communiquer avec l'investigateur responsable de l'étude: Dr. Matthias G. Friedrich 514 934-1934 poste: 34630. Pour toute question concernant vos droits en tant que participant à cette étude, ou si vous avez des commentaires ou si vous souhaitez déposer une plainte, vous pouvez communiquer avec le commissaire aux plaintes contre l'hôpital / l'ombudsman au numéro suivant: (514) 934-1934, poste 35655.

ASPECTS ÉTHIQUES DE L'ÉTUDE
Le comité d'éthique de la recherche du Centre Universitaire de Santé McGill a revu cette étude et est responsable de son suivi.

Appendix C

Participation Invitation Email for Physicians

Dear Dr. [Last Name],

As a physician affiliated with the MUHC, you are invited to participate in a research study entitled *Patient and Physician Preferences for Non-Invasive Cardiac Diagnostic Imaging Technologies: A Discrete Choice Experiment (3P)*. This study is being conducted under the supervision of Dr. Gillian Bartlett and Dr. Matthias Friedrich.

The 3P study is funded by the RI-MUHC and by the McGill University Department of Family Medicine, and its purpose is to contribute to the understanding of patient and physician preferences for non-invasive diagnostic cardiovascular imaging technologies.

Your participation is anonymous and involves answering a **10-minute online questionnaire**.

Over 140 patients from the RVH cardiology clinic have already conveyed their preferences by completing the questionnaire. As a physician, we need your help to have a better understanding of the physicians' preferences. By clicking the link, you will be redirected to the online questionnaire.

- Click this link to complete the questionnaire **in English**: Questionnaire in English

- Cliquez sur ce lien pour le questionnaire **en Français**: Questionnaire en Français

We thank you in advance for your participation.

If you would like to have more information about this study, we invite you to read the study implied consent form:
Implied Consent Form in English, Implied Consent Form in French

Do not hesitate to contact me should you have any questions.

Sincerely,

Thomas Bertrand
BA (Hons), M.Sc. Student
McGill University | Department of Family Medicine
McGill University Health Centre | Research Institute
Thomas.Bertrand@mail.mcgill.ca

Appendix D

Implied Consent for Physicians (English Version)

1. INTRODUCTION
You are invited to participate in a research study entitled Patient and Physician Preferences for Non-Invasive Cardiac Diagnostic Imaging Technologies: A Discrete Choice Experiment. This study is being conducted by Thomas Bertrand, MSc student, under the supervision of Dr. Matthias Friedrich and Dr. Gillian Bartlett.
2. OVERVIEW AND PURPOSE OF THE STUDY
The purpose of this study is to investigate and compare patients' and physicians' preferences toward different characteristics of cardiac imaging tests for diagnosing coronary artery disease. We hope that the study results will contribute to scientific knowledge regarding patient and physician preferences in the field of cardiovascular imaging.
3. STUDY PROCEDURES
This research will focus on understanding which test features you prefer and see how it can influence your decision making by answering an online questionnaire. The questionnaire will include a variety of questions from which you will need to choose between two test alternatives. You will be asked to select your preferred test alternative. The questionnaire will take approximately 10 minutes to complete.
4. RISKS ASSOCIATED WITH THE STUDY
There are no foreseeable risks associated with participating in this study.
5. BENEFITS ASSOCIATED WITH THE STUDY
There is no direct benefit to you for participating in this study.
6. CONFIDENTIALITY AND RIGHT TO WITHDRAW
This questionnaire will remain completely anonymous and no personal information about you will be collected. The investigators affirm and uphold the principle of the participant's right to privacy and that they shall comply with applicable privacy laws. Your participation to this study is voluntary. Thus, it is your right to decide to participate or not, and your decision will not affect you or your employment.
7. SHARING STUDY RESULTS
Results from this study will be presented at conferences and published in journals.
8. FUNDING OF THE STUDY
This study is being funded by internal studentships from the RI-MUHC and the McGill University Faculty of Medicine.
9. CONFLICT OF INTEREST
The researchers have no conflict of interest to declare.
10. CONTACT INFORMATION
If you have questions about the study you can communicate with the investigator in charge of the study: Dr. Matthias G. Friedrich 514 934-1934 ext: 34630. For any questions concerning your rights as a person taking part in this study, or if you have comments or wish to file a complaint, you can communicate with the Hospital Complaint Commissioner/Ombudsman at the following number: (514) 934-1934 ext:35655.
11. REVIEW OF THE ETHICAL ASPECTS OF THE STUDY
The McGill University Health Centre Research Ethics Board reviewed this study and is responsible for monitoring the study.
ACCESS THE QUESTIONNAIRE
If you have read this letter and would like to participate, please follow the link below:
https://3P.sawtoothsoftware.com/login.html

Sincerely,
Thomas Bertrand
Thomas.Bertrand@mail.mcgill.ca

Appendix E

Implied Consent for Physicians (French Version)

1. INTRODUCTION
Vous êtes invités à participer à une étude de recherche intitulée Préférence des Patients et des Médecins pour les Technologies Non-Invasive d'Imagerie Diagnostique Cardiaque: Expérimentation de Choix Discrets. Cette étude est menée par Thomas Bertrand, étudiant à la maîtrise, sous la supervision du Dr. Matthias Friedrich et du Dr. Gillian Bartlett.
2. BUT DE L'ÉTUDE
Le but de cette étude est de comprendre et de comparer les préférences des patients et des médecins à l'égard des différentes caractéristiques des tests d'imagerie cardiaque pour le diagnostic des maladies coronariennes. Nous espérons que les résultats de l'étude contribueront à la connaissance scientifique des préférences des patients et des médecins dans le domaine de l'imagerie cardiovasculaire.
3. PROCÉDURES DE L'ÉTUDE
Cette recherche se concentrera sur la compréhension des caractéristiques de test que vous préférez et sur la façon dont elles peuvent influencer votre prise de décision en répondant à un questionnaire en ligne. Le questionnaire inclura une variété de questions à partir desquelles vous devrez choisir entre deux alternatives de test. Il vous sera demandé de sélectionner votre alternative de test préférée. Le questionnaire prendra environ 20 minutes à compléter.
4. RISQUES ASSOCIÉS À L'ÉTUDE
Il n'y a pas de risques prévisibles associés à la participation à cette étude.
5. BÉNÉFICES ASSOCIÉS À L'ÉTUDE
Vous n'avez aucun avantage direct à participer à cette étude.
6. CONFIDENTIALITÉ ET DROIT DE REFUS
Ce questionnaire restera totalement anonyme et aucune information personnelle vous concernant ne sera collectée. Les enquêteurs affirment et défendent le principe du droit au respect de la vie privée des participants et qu'ils se conforment aux lois applicables en matière de protection de la vie privée. Votre participation à cette étude est volontaire. Ainsi, vous avez le droit de décider de participer ou non et votre décision ne vous affectera pas, vous ou votre emploi.
7. PARTAGE DES RÉSULTATS
Les résultats de cette étude seront présentés lors de conférences et publiés dans des revues.
8. FINANCEMENT DE L'ÉTUDE
Cette étude est financée par des étudiants internes de l'IR-CUSM et de la Faculté de médecine
de l'Université McGill.
9. CONFLITS D'INTÉRÊTS
Les chercheurs n'ont aucun conflit d'intérêt à déclarer.
10. INFORMATION DE CONTACT
Si vous avez des questions sur l'étude, vous pouvez communiquer avec l'investigateur responsable de l'étude: Dr. Matthias G. Friedrich 514 934-1934 poste: 34630. Pour toute question concernant vos droits en tant que participant à cette étude, ou si vous avez des commentaires ou si vous souhaitez déposer une plainte, vous pouvez communiquer avec le commissaire aux plaintes contre l'hôpital / l'ombudsman au numéro suivant: (514) 934-1934, poste 35655.
11. ASPECTS ÉTHIQUES DE L'ÉTUDE
Le comité d'éthique de la recherche du Centre Universitaire de Santé McGill a revu cette étude et est responsable de son suivi.
ACCÉDER AU QUESTIONNAIRE
Si vous avez lu cette lettre et que vous souhaitez participer, veuillez suivre le lien ci-dessous:
https://3P.sawtoothsoftware.com/3Pfr/login.html

Cordialement,
Thomas Bertrand
Thomas.Bertrand@mail.mcgill.ca

Appendix F

Demographic Questionnaire (English Version)

Centre universitaire de santé McGill — McGill University Health Centre

Part 1

First, please answer a few questions about yourself.

Do you answer this questionnaire as a patient or as a physician?

- ◯ As a patient
- ◯ As a physician

If you are a physician, please indicate your medical speciality?

- ◯ Family medicine
- ◯ Cardiology
- ◯ Other
- ◯ None of the above (I am a patient).

What is your age, in years?

- Years

What is your gender?

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer

What is the highest level of education you have completed?

- ◯ Elementary school
- ◯ High school
- ◯ College or technique (3-year program)
- ◯ University
- ◯ I prefer not to answer

What was your household's total income last year?

- ◯ Less than $25,000
- ◯ $25,000 to $49,999
- ◯ $50,000 to $74,999
- ◯ $75,000 to $99,999
- ◯ $100,000 to $149,999
- ◯ $150,000 or more
- ◯ Prefer not to answer

2

Centre universitaire de santé McGill | McGill University Health Centre

Which of these cardiac imaging modalities are you most familiar with?

(You may select more than one modality)

- [ ] Magnetic resonance imaging (MRI)
- [ ] Echography
- [ ] Computed tomography (CT)
- [ ] Single-photon emission computed tomography (SPECT)
- [ ] Positron emission tomography (PET) scan
- [ ] None of the above

Which of these cardiac imaging modalities have you personally experienced (or ordered)?

(You may select more than one modality)

- [ ] Magnetic resonance imaging (MRI)
- [ ] Echography
- [ ] Computed tomography (CT)
- [ ] Single-photon emission computed tomography (SPECT)
- [ ] Positron emission tomography (PET) scan
- [ ] None of the above

Appendix G

Demographic Questionnaire (French Version)

Centre universitaire de santé McGill — McGill University Health Centre

Part 1

D'abord, veuillez répondre à quelques questions vous concernant

Répondez-vous à ce questionnaire en tant que patient ou en tant que médecin?

- ◯ En tant que patient
- ◯ En tant que médecin

Si vous êtes médecin, veuillez indiquer votre spécialité médicale.

- ◯ Aucune, je suis un patient
- ◯ Médecine Familiale
- ◯ Cardiologie
- ◯ Autre

Quel âge avez-vous, en années?

- Années

De quel sexe êtes-vous?

- ◯ Homme
- ◯ Femme
- ◯ Je préfère ne pas répondre

Quel est le niveau d'éducation le plus élevé que vous avez terminé?

- ◯ École primaire
- ◯ École secondaire
- ◯ CEGEP ou technique (programme de 3 ans)
- ◯ Université
- ◯ Je préfère ne pas répondre

Quel était le revenu total de votre famille l'an dernier?

- ◯ Moins de 25,000$
- ◯ 25,000$ à 49,999$
- ◯ 50,000$ à 74,999$
- ◯ 75,000$ à 99,999$
- ◯ 100,000$ à 149,999$
- ◯ 150,000$ ou plus
- ◯ Je préfère ne pas répondre

2

Centre universitaire de santé McGill | McGill University Health Centre

Parmi les modalités d'imagerie cardiovasculaire suivantes, lesquelles vous sont plus familières?

(Vous pouvez sélectionner plus d'une modalité)

- [ ] Imagerie par résonance magnétique (IRM)
- [ ] Échographie
- [ ] Tomodensitométrie (CT)
- [ ] Tomographie par émission monophotonique (TEM)
- [ ] Tomographie par émission de positrons (TEP)
- [ ] Aucune de ces réponses

Parmi les modalités d'imagerie cardiovasculaire suivantes, lesquelles avez-vous personnellement expérimenté(s) (ou prescris)?

(You may select more than one modality)

- [ ] Imagerie par résonance magnétique (IRM)
- [ ] Échographie
- [ ] Tomodensitométrie (CT)
- [ ] Tomographie par émission monophotonique (TEM)
- [ ] Tomographie par émission de positrons (TEP)
- [ ] Aucune de ces réponses

Appendix H

Coding Manual

Language

1: French
2: English

Question 1 - Group

1: Patient
2: Physician

Question 2 - Speciality

1: Family Medicine
2: Cardiology
3: Other
4: None of the above

Question 3 - Age

1: Value#

Question 4 - Gender

1: Male
2: Female

Question 5 - Education

1: Elementary
2: High
3: College
4: University
5: Prefer not to answer

Question 6 - Income

1: Less than $25,000
2: $25,000 to $49,999
3: $50,000 to $74,999
4: $75,000 to $99,999
5: $100,000 to $149,999
6: $150,000 or more
7: Prefer not to answer

Question 6 – Familiar Modalities

0: No
1: Yes

Question 7 – Experienced Modalities

0: No
1: Yes

Questionnaire Version

1: Version 1
2: Version 2
3: Version 3
4: Version 4
5: Version 5
6: Version 6
7: Version 7

CBC 1 through 13

1: A
2: B

Question 9 - Difficulty

1: Very Easy
2: Easy
3: Not easy, not difficult
4: Difficult
5: Very difficult

- END OF 3P CODING MANUAL -

Appendix I

Questionnaire Versions – Levels of First Choice Alternative

VERSION 1:

Type of Procedure:	Pharmacological agents
Duration:	60 minutes
Out-of-pocket Cost:	$2000
Type of Scanner:	No scanner
Risks and side-effects:	Radiation
Test Accuracy:	90%

VERSION 2:

Type of Procedure:	Pharmacological agents
Duration:	60 minutes
Out-of-pocket Cost:	$1000
Type of Scanner:	Full body scanner
Risks and side-effects:	Pain
Test Accuracy:	70%

VERSION 3:

Type of Procedure:	Pharmacological agents
Duration:	60 minutes
Out-of-pocket Cost:	$1500
Type of Scanner:	Partial body scanner
Risks and side-effects:	Tingling in the fingers
Test Accuracy:	90%

VERSION 4:

Type of Procedure:	Pharmacological agents
Duration:	60 minutes
Out-of-pocket Cost:	$1500
Type of Scanner:	Partial body scanner
Risks and side-effects:	Radiation
Test Accuracy:	80%

VERSION 5:

Type of Procedure:	Pharmacological agents
Duration:	30 minutes
Out-of-pocket Cost:	$1500
Type of Scanner:	No scanner
Risks and side-effects:	Tingling in the fingers
Test Accuracy:	90%

VERSION 6:

Type of Procedure:	Pharmacological agents

Duration:	30 minutes
Out-of-pocket Cost:	$500
Type of Scanner:	No scanner
Risks and side-effects:	Radiation
Test Accuracy:	80%

VERSION 7:

Type of Procedure:	Pharmacological agents
Duration:	60 minutes
Out-of-pocket Cost:	$1500
Type of Scanner:	Partial body scanner
Risks and side-effects:	Tingling in the fingers
Test Accuracy:	80%

- END OF 3P QUESTIONNAIRE VERSIONS -

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TITLE OF THESIS: _____

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I further promise to inform any person to whom I may hereafter assign or license my copyright in my thesis of the rights granted by me to Library and Archives Canada in this non-exclusive license.

Signature	**Date**